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GIRLS' BUILDING.

ANNUAL REPORT

OF THE

AGRICULTURAL EXPERIMENT STATION

OF THE

UNIVERSITY OF MINNESOTA.

Fiscal Year July 1, 1897, to June 30, 1898.

DELANO, MINN.:
EAGLE PRINTING CO., PRINTERS.
1898.

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OFFICERS OF THE STATION:

WM. M. LIGGETT - - - - - - - - - -	Director.
WILLET M. HAYS, M. Agr., - - - - - -	Agriculturist.
SAMUEL B. GREEN, B. S. - - - - - -	Horticulturist.
OTTO LUGGER, Ph. D., - -	Entomologist and Botanist.
HARRY SNYDER, B. S., - - - - - - - - -	Chemist.
T. L. HÆCKER, - - - - - - - - -	Dairy Husbandry.
M. H. REYNOLDS, M. D., V. M., - - - - -	Veterinarian.
THOS. SHAW, - - - - - - - -	Animal Husbandry.
T. A. HOVERSTAD, B. Agr., - -	Asst. in Agr., Crookston.
ANDREW BOSS, - - - - -	Asst. in Agr., Univ. Farm.
R. S. MACKINTOSH, - - -	Asst. in Hort., Univ. Farm.
J. A. VYE, - - - - - - - - - - - - -	Secretary.

☞The Bulletins of this Station are mailed free to all residents of the State who make application for them.

MINNEAPOLIS, MINN., July 1, 1898.

To His Excellency, David M. Clough, Governor of Minnesota:

I have the honor to transmit to you herewith the annual report of the Agricultural Experiment Station of the University of Minnesota for the fiscal year ending June 30, 1898.

JOHN S. PILLSBURY,
President Board of Regents.

243017

List of Bulletins Published during the fiscal year 1898.

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PRESS BULLETIN No. 9, Jan. 2, 1898.—A Complete List of Publications, 1888 to 1897, inclusive.....

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BULLETIN No. 54.—Human Food Investigations.—The Gluten of Wheat.—The Digestibility and Composition of Bread.—The Loss of Food Value by Prolonged Fermentation in Bread Making.—The Digestibility of Potatoes, and the Loss of Food Value when Potatoes, Carrots, and Cabbages are Boiled in Different Ways.—The Rational Feeding of Men..... 37

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REPORT

OF THE

Director of the Experiment Station Corps.

This annual report of the agricultural experiment station of the University of Minnesota contains copies of the bulletins published during the year from June 30th, 1897, to July 1st, 1898, inclusive, and a detailed statement of the receipts and expenditures of the annual appropriation from the United States treasury. Following this is a summarized statement of receipts and disbursements from June 30th, 1897, to July 1st, 1898, showing that the University of Minnesota has expended $11,086.57 more in carrying on the experimental work than the "Hatch" fund ($15,000) received from the United States government. Following this statement is a financial report of the two stations established by an act of the legislature in 1895, one at Crookston, Minnesota, the other at Grand Rapids, Minnesota. Also statement of the station previously established on the farm of Mr. O. C. Gregg, superintendent of the Farmers' Institutes of Minnesota, near Lynd, Lyon county, Minnesota.

THE UNITED STATES ARPROPRIATION, 1897-8.

Dr.

To receipts from the Treasurer of the United States as per appropriation for fiscal year ending June 30th, 1898, as per act of Congress approved March 2, 1887		$15,000.00
Cr.		
By Salaries	$10,196.60	
Labor	1,572.15	
Publications	271.00	
Postage and stationery	194.04	
Freight and express	4.23	
Heat, light and water	86.03	
Chemical supplies	203.09	
Seeds, plants, and sundry supplies	290.28	
Feeding stuffs	547.58	
Tools, implements and machinery	133.85	
Furniture and fixtures	4.00	
Scientific apparatus	52.50	
Live stock	1,048.60	
Traveling expenses	35.09	
Contingent expenses	261.16	
Building and repairs	99.80	
	$15,000.00	15,000.00

FINANCIAL STATEMENT.

Statement of disbursements and receipts of the Minnesota Agricultural Experiment Station for the twelve months beginning July 1st, 1897, and ending June 30th, 1898, inclusive.

	Disbursements.	Receipts.	Cash Outlay.
Station	$ 9,464.20	$ 523.79	$ 8,940.41
Agriculture	5,741.57	310.02	5,431.55
Horticulture	3,703.10	688.87	3,014.23
Chemistry	1,916.65	105.60	1,811.05
Entomology	1,031.81	.....	1,031.81
Veterinary	1,522.59	444.12	1,078.47
Dairy	1,349.99	.....	1,349.99
Animal Husbandry	5,803.10	2,940.66	2,862.44
	$30,533.01	$5,013.06	$25,519.95
Crookston	4,594.84	1,845.67	2,749.17
Grand Rapids	2,410.90	1,156.60	1,254.30
	$ 7,005.74	$3,002.27	$ 4,003.47
Coteau	*566.62	.....	566.62

*Paid by current expense.

The work carried on at the Northwest experiment farm near Crookston under the supervision of T. A. Hoverstad, has been along the same lines outlined in the annual report for 1896. Much work has been done in putting the farm in condition for experimental work, in draining the land, and in making roads, fences, etc. The farm barn which was destroyed by fire, caused by lightning, July 28th, 1897, has been rebuilt. The damage done by this fire seriously delayed much work and made it impossible to carry out intended improvements. In field work, varieties of wheat, oats, barley, and flax have been tested. The better varieties have been grown in larger quantities and sold for seed to farmers in the various parts of the state. Forage and pastures from annual crops have been tried on a small scale. This has been carried far enough to show that in this field work can be carried on that will be fruitful of very much good to the farmer. Varieties of the different species of vegetables have been grown with great success. Small fruit bushes have been planted, fruit trees of apple and plum have been set in the orchard. So far the trees and bushes are too young to bear fruit, but they have nearly all made good growth. Several acres have been planted to forest trees with varying results. The grove planted in '96 now makes quite a respectable showing. Of the many species of grasses sown, some of the more recently introduced are very promising. Live stock experiments have been largely confined to horses. The purpose has been to determine the amount to feed a horse at work and when idle; the relative proportion of roughage to concentrates; and the relative feeding value of the various rough foods for the horse. In a smaller way experiments have been prosecuted in feeding and pasturing cattle, hogs, and sheep.

Warren W. Pendergast of the Northeast experiment farm located at Grand Rapids, Minnesota, died August 26th, 1897. He was entrusted with the responsibility of the superintendency when the station was located in the spring of 1896. From the first he gave vigorous attention to planning new fields, buildings, roads, fences, investigation of soils, drainage of swamps, protection of young timber, reforesting

the burned areas, and the development of grasses, grain, and forage foods.

During the brief time he was engaged in this important work, he acquired much valuable information by his experience and observations and had plans for the future development of the station that merited approval. His marked ability, clear perception, strength of purpose in accomplishing work, his rare good sense in dealing with men and his splendid character peculiarly fitted him for the position he so ably filled. His loss is most severe. The work during the summer and fall of '97 was placed in charge of R. W. Clark, who was assisting Mr. Pendergast at the time of his death. On February 1st, 1898, Herman H. Chapman, a graduate of the State University and School of Agriculture, was appointed superintendent of the station and the work has been continued along the lines mapped out when the station was established. Much valuable information as to methods and cost of clearing lands in this region has been acquired. The farm now has 95 acres of land from which the stumps have been completely removed and practically freed from roots and stones. In the three years large fields have been transformed from a heavily wooded condition to one of perfect tilth, permitting the use of all modern farm machinery. The work of subduing the peat or muskeg swamp land is progressing very satisfactorily. An extensive open drain has lowered the water level in two of these swamps permitting the work of burning and breaking them to commence. The management of the fields is being carefully studied with especial reference to maintaining the fertility of that portion of the farm on which the soil is light and sandy. Manuring and the use of green manures and fertilizing crops is an important part of this work. The tests conducted the last three years to determine, as far as possible, the varieties of grain and other crops best adapted to the soil and climate, have placed a large store of information at the disposal of settlers in this region. Especial attention has been given to grain and root crops, including potatoes. It is hoped that a variety of corn will be developed that will far surpass any that can be grown there at present. A large quantity of an-

nual forage crops of different kinds is raised on the farm to illustrate the practicability and advantages of this method of feeding dairy and other stock. Tests of the different grasses for permanent meadow are being conducted to show their hardihood and suitability to different soil conditions. The farm buildings are being remodeled and improved to serve as models for the incoming settlers. A large vegetable garden has shown the possibility of raising nearly all kinds of vegetables of the finest quality. A great many ornamental shrubs and flowers have been tested for hardiness. The orchard is now in its third year and a few varieties of apples and crabs give promise of being able to withstand the climate. Small fruits, as raspberries and strawberries, have been very successful. A part of the farm is devoted to experiments in tree culture in co-operation with the United States Division of Forestry. Seedlings and transplants of the White, Norway, Jack, Scotch, and Austrian pines, from one to three years old, show splendid growth. The co-operative experiment in the effect of locality on the vitality of seed has given instructive results.

The experiment work in charge of Wm. G. Smith at the Coteau Farm started in 1894 under Prof. Hays has resolved itself into a study of soil moisture, soil fertility, production of forage crops, and forestry protection. The soil moisture studies are facilitated very much by the use of an electrical device perfected by Dr. Milton Whitney, chief of the Division of Soils, Washington, D. C. The principle on which this method rests is that the electrical conductivity of soils varies regularly, according to fixed laws, with the amount of water in the soil. By this method the moisture conditions of the soil are noted daily instead of in periods of from ten to fifteen days as by the old method. The temperature of the soil is taken by the same device. Some two dozen temperature and moisture observations can be made with this device while one moisture determination is being made by the old method. Mulching, surface cultivation, spring and fall plowing, sub-surface packing and sub-soiling are tested for their moisture and temperature conditions with and without crops, the object being to find the treatment that not only

conserves moisture but which also gives rise to moisture and temperature conditions in which the decomposition of organic matter is quickly brought about and the best crops produced. A complete set of meteorological instruments furnished by the weather bureau enables us to secure a complete weather record to use in connection with the soil moisture and temperature work. This section of the state lies in the driest portion of Minnesota and the method of soil culture that will best conserve the soil water for the use of crops here should succeed elsewhere. During the past two years data have been gathered along this line that are being prepared for publication in a much more comprehensive form than anything of the kind presented before. When it is remembered that from three to five hundred tons of water are necessary in growing one ton of field crop the importance of this work is more evident. The soil fertility studies are shaped by the suggestion that the products of organic decay, uniting as they do with the inert minerals of the soil, give rise to important plant foods. The practical methods of thus building up the soil are being carefully studied. The significance of using a leguminous crop every fourth or fifth year to supply the food which the non-leguminous plants consume, is also receiving systematic attention. Adding organic matter to the soil by pasturing animals on summer crops and grass lands is also under way. This year three crops were grown on the same piece of land and each crop was pastured off as soon as ready. In this manner much organic matter is added to the soil. The size of fields and the cost of fencing comes up for solution in connection with this system of field management, while at the same time better crops may be grown. The value of this method of soil culture is to be compared with continuous wheat growing. Methods of grass and clover culture are a necessary study in connection with the soil fertility work. Much success attends the grass and clover experiments. The forestry plantation started in 1894 under the direction of Prof. S. B. Green is doing well. It is much appreciated by those who have heretofore been unsuccessful in tree growing. Quick growing trees, such as the willow and caragana, are

planted for protection to the slower growing evergreens and deciduous trees. In this work we are aided very much by the active interest of Supt. O. C. Gregg on whose farm the work is done. He is having marked success in growing small fruits and orchard fruits aided by this system of forestry protection. In the field work he is giving substantial aid by shaping his farm into demonstration fields along the lines suggested by the experiment work.

The work in the division of agriculture is largely a continuation of that outlined in previous reports. The experiments in farm and field management are progressing year by year. The present year marks the end of the first cycle of five years in the rotation experiments in which the division of chemistry shares with the agricultural. The soil, soil water and the roots of field crops have been especially studied at University and Coteau Farms. The experiments with pastures, permanent, rotation, summer and shift, though requiring many years for their completion are progressing at University Farm, and at the outside farms co-operative work has been started. The efforts in seeking the best varieties of each kind of field crops for each portion of the state that better kinds may be disseminated are being continued and with the aid of three sub-stations valuable results are being reached. The breeding of the best varieties of our staple crops is being carried on with system and on a sufficiently extensive scale to insure good results. A good variety of corn has been disseminated and others are being bred for large yield and other good qualities. Several new varieties each of wheat, flax, timothy, field peas and bromus promise added yields. The methods of breeding plants are year by year being worked out in a manner which gives promise of important economic results. In connection with this breeding the floral organs of the leading field crops are being described and figures drawn. The gross anatomy of the stems and roots of the important crop plants likewise are being studied and sketches are being made for publication. Experiments are continued in preparing the soils. Methods of planting and cultivating the staple crops, harvesting and storing fodders are under experimentation. Prof. W. M.

Hays and Mr. Andrew Boss express special satisfaction and gratitude for the loyal and efficient services of the various college and school students and the workmen who have been interested in this division during the past year. Training young men in the science and art of agricultural experimentation is a most important function of the station.

In the division of horticulture the experiment work has been done along about the same lines as indicated in the report of last year. No bulletin has been published but the reports of the division have been printed in the proceedings of the Minnesota Horticultural Society. A large amount of time has been used in preparing material for a text book on forestry for use in the School and College of Agriculture that will be published the coming year so as to be in readiness at the opening of the school. Considerable attention has been given to the care and management of the grounds about our school buildings, grading around and laying out drives adjacent to the new Girls' Building and Power House and to the laying of new cement sidewalks from the Home Building to the Laboratory and Drill Hall. A new and very complete card index system has been adopted for keeping the records of our orchards, small fruit plantations, vegetables, trees and shrubs. This will undoubtedly help us very much in keeping track of our large and increasing collection of plants. Several hundred record photographs have been added to the collection already on hand, which now numbers over six hundred. The collections of fruit trees and plants, ornamental and timber trees, shrubs, etc. have been increased by suitable additions so that they are now very complete. About seventy varieties of apples have fruited the season just passed and considering the fact that our location and soil are poorly adapted to the growing of apples the results have been very satisfactory. Nearly all of our varieties of plums, raspberries, strawberries, blackberries, and gooseberries fruited heavily. Grapes yielded a fair crop. The forestry plantation has been increased by additions of much interest and it is in excellent condition. About sixty varieties of potatoes of the newer kinds have been raised in competitive trial and the results tabulated. Enough varieties of other

vegetables have been raised to keep our records up to date and in sufficient quantity in most cases to supply the Dining Hall. The studies of potato machinery have been continued and are regarded with much interest by visitors and students. The timely and abundant rains did away with the necessity of using our irrigation plant to any great extent. Considerable interest has been shown in the results of some very successful experiments carried on here to destroy plum aphis by the use of a tent and tobacco smoke. Prof. Green has advised with the superintendents of the Northwest and Northeast Experiment Stations and with Supt. O. C. Gregg of Coteau Farm as to the horticultural and forestry work at these places.

In the division of entomology bulletin No. 55 was issued. It is a text book of nearly 300 pages in which all the grasshoppers, locusts, crickets, cockroaches, and allied insects found in Minnesota are fully described and illustrated. Both their external and internal anatomy is given. The methods used to combat these destructive insects successfully are discussed in detail and a glossary of the terms used assists the reader to understand the descriptions which are necessarily somewhat technical. Over 6000 tin boxes filled with spores to combat the chinch-bugs were mailed to those desiring to use them, but especially to millers who distributed this material among their farmer customers. The results have been very gratifying in numerous instances, as indicated by many letters.

Generally speaking the past season has been a remarkable one so far as insects are concerned, and the damage caused by these pests has been exceptionally slight, excepting in some individual cases. Reports of injuries to our grains, caused by the frit-fly, the wheat steam maggot, and the Hessian fly, were less numerous than in the previous year, while the number of letters in regard to the wire-worms, several kinds of cut-worms, and a boring cut-worm became very numerous for a time, showing that these insects are increasing in numbers and destructiveness. Grave fears were entertained for a time that the genuine Rocky Mountain locust had reached or would reached our state. Happily

these fears were unfounded, as the nearest region in which this insect occurred in destructive numbers was some 100 miles west of our boundary line in North Dakota. At the invitation of the Northern Pacific Railway Company, and later of that of the Soo line, the entomologist visited the infested region and showed the farmers how to go to work to prevent further injuries. Later the proper authorities in North Dakota took the matter in hand, and with very marked results. In some of our older cities the shade trees are badly infested with the cottony scale and there is great danger that many kinds of trees will be killed if no proper steps are taken to destroy this pest, which is rapidly spreading to many other cities and even to wind breaks and timber claims. The entomologist made a number of trips to arouse the people in the infested cities to united action to save their trees. A number of nurseries were also visited to inspect the stock so that it could be sold to other states and to Canada. During the busy season it is not unusual for the entomologist to receive fifty or more letters per day, hence correspondents cannot always expect to receive lengthy answers. The museum, which contains not alone entomological specimens but also mounted specimens of mammals and birds, has grown very rapidly in size and in importance, and is not alone visited by the students but by many visitors and quite frequently by classes from the public schools of the twin cities.

In the chemical division bulletins 53, 54 and 56 have been issued. The most important subjects treated were: Effects of the rotation of crops upon the fertility and humus content of soils, and the production of humus from manures; the gluten of wheat, digestibility and composition of bread, losses in boiling vegetables, the rational feeding of men; summary of investigations of sugar beets from 1888 to 1898. In connection with the office of Experiment Stations of the U. S. Department of Agriculture, Bulletin No. 43 Department of Agriculture was published entitled "Losses in Boiling Vegetables and the Composition and Digestibility of Potatoes and Eggs." Prof. Snyder has work in progress as follows: *Fodders.* Factors, as seeds, soils and cultivations,

which influence composition and feeding value. *Manures.* Losses which occur in the handling of manures. Comparative value of different farm manures. *Ventilation of stables.* The composition of air from poor and from well ventilated stables. *Soils.* Influence of different methods of cultivation upon the moisture content of soils. Analysis of soils from farms where the fertility has been kept up and from farms that have declined in crop-producing power. Work as referee on soils and ash for the Association of Official Agricultural Chemists. *Human Foods.* Continuation of the work outlined in 1895. In 1897 a study was made of the chemical changes which take place in bread making. This work was carried on in co-operation with the U. S. Department of Agriculture. Twenty-six digestion experiments were made with milch cows, in connection with the dairy division, to determine the relative feeding value of corn fodder cut at different dates, etc.; and analyses of crops raised on rotation plots in co-operation with the agricultural division were made. A free analysis is made of all agricultural materials sent in by farmers of the state, provided the work is of such a nature that it can be used for publication in bulletins. The station does not undertake to make analyses of materials as mineral water, minerals, or general assay work. Numerous analyses have also been made of feeding stuffs as bran, oil meal and milled products, supposed to be adulterated. Some little time has also been spent in the analysis of limestones for different localities where beet sugar factories are contemplated. The result of this work has been highly satisfactory. Four localities have been found where the limestone is of sufficiently high purity to allow its use in the manufacture of beet sugar. Many analyses have also been made of adulterated flour products collected in the large trade centers as Chicago, Cincinnati, Richmond, etc. This work was done because of the threatened injury of adulterated flour to our wheat and milling industry. These analyses were made at the time the pure flour law was before congress with the object of showing the extent to which flour was adulterated.

The work in the dairy division the past year, as well as

the five previous years, has been directed chiefly toward determining the cost of milk production. During the winters of 1895-96 and 1896-97 experiments were carried on to ascertain why some cows in the station herd made so large returns in dairy products while others with like care and under similar conditions produced a much smaller return. This has been a very complicated problem to solve as it involves several distinct questions: First, the amount of food nutrients needed for bodily maintenance; second, the amount of nutritive substance required for a pound of gain; and third, the amount of food nutrients represented per pound loss of bodily weight. The food nutrients needed for bodily maintenance are not fully understood, since some cows gain during their period of lactation while others lose, and some produce more solids, not fat, in their milk, Prof. Haecker has found it exceedingly difficult to trace the disposition made of the nutritive substance in the food taken. In order to ascertain the amount of food required to maintain the body, several cows that had passed the period of usefulness in the dairy and had gone perfectly dry, were used in this part of the work with new and highly satisfactory results. The experiment in rearing dairy calves is still in progress with most promising results, and will be the subject of a bulletin to be prepared for publication early next season. A number of experiments are in progress with a view to getting all the data necessary for a complete analysis of the cow best adapted for the dairy, the work being confined to one line, that of economic milk production.

In the veterinary division the work during the past year has been largely with hog cholera, which has prevailed to a serious extent over the entire southern portion of the state. The infection probably came from Iowa and Nebraska, and spread rapidly during the seasons of 1896 and 1897. It has been the plan to scatter information among the farmers concerning the disease and arouse local health officers and stockmen to the seriousness of the situation. The station has issued two editions of press bulletin No. 5, both of which are exhausted. This bulletin deals with the cause and nature of the disease, symptoms, how it is spread, mistakes commonly

made by farmers in dealing with it, and gives full information concerning what can be done in case the disease appears. Dr. Reynolds has spent considerable time in the infected district with the State Farmers' Institute talking on hog cholera. During this first season with work of this kind it has been difficult to get farmers and local health officers to realize that much could be done by proper precautions to limit the spread of hog cholera and even to entirely avoid it. It is quite evident that we have two infectious swine diseases in this state, swine plague and hog cholera; and for some reason not yet clearly explained the two diseases almost invariably appear together and hogs that die usually show a mixed infection. While there can be no doubt that these diseases are caused by specific germs, it is believed that other factors have to do with the causation. Conditions of food and care undoubtedly have quite an important bearing, and the veterinary division has been studying this feature of the problem. For this purpose a small blank was gotten out for field data and when a blank is filled out for each outbreak we have full information concerning the conditions under which the outbreak occurred. During the season of 1897 the experiment station has also been conducting some inoculation experiments with hog cholera serum. This work has been done in collaboration with the veterinary division of the Nebraska station. Dr. Peters of the latter station furnished the serum and did the laboratory work; Dr. Reynolds has planned and managed the field work for this state. The results will be published in bulletin form when completed. The results of the test experiments were not as satisfactory as was expected, but the work is to be continued, and it is to be hoped that we will soon have a vaccine that will give immunity against hog cholera for a reasonable period. It is difficult to secure a vaccine that will give a sufficient period of immunity, and be at the same time concentrated and cheaply produced. The Bureau of Animal Industry has promised to furnish us limited quantities of the new government serum and we expect to do some experimental work with this next year.

The animal husbandry department has carried on num-

erous experiments with cattle and sheep. The experiments with swine were rudely broken off for a time by the visitation of hog cholera referred to in the preceding report, but extensive experiments in the line of cross breeding and of growing bacon are now under way. Steers from the range have been fattened on light and heavy rations to determine the relative value of these. Steers of different types have been fed to demonstrate the influence of type on meat production, and cattle have been grown for meat from birth to finish to determine the outcome in cost and profit. Experiments have been conducted in fattening home grown and range lambs on similar foods, that the results may be compared in fattening range lambs on various foods to determine their practicability on the average farm, and also the relative suitability of the foods used; and in fattening range wethers and lambs respectively, to ascertain which of these lines of work is attended with the greatest profit. Most extensive and highly successful experiments have been conducted in growing summer forage for sheep. These experiments have drawn no little attention and favorable comment from all parts of the United States and Canada. Comprehensive experiments are now being carried on in growing winter fodders for sheep. Three bulletins have been issued since the previous report, covering ten experiments, and a fourth is now nearing completion. This department has also produced a text book, "The Study of Breeds," which is now being used in some of the foremost of our agricultural colleges.

The farmers of Minnesota as well as the business and professional men of the cities have shown a great interest in our work during this year. Many delegations of farmers from the various counties of the state have visited the farm this summer. During the past winter we received many visitations from farmer delegations as well as from the chamber of commerce, St. Paul, and the board of trade, Minneapolis. Scarcely a day passes that we do not have from five to twenty visitors. The Grange people and also the Horticultural Society make this their home for their annual meetings. All are cordially received, as their coming is

an evidence of interest in our work and most encouraging to those who are devoting their energies and best thought to giving assistance to all who are pursuing the general lines of agriculture.

Since the organization of this station there has not been such an earnest desire for information and a lively demand for help along the lines of agriculture as this year. Our mail is increasing daily, and we make it a rule of this station to answer promptly every inquiry, either by a personal letter or mailing some printed matter giving the information desired.

Seven bulletins have been published during the year. Twenty thousand copies of each issue, excepting 53 and 55 (the former seventeen thousand, the latter fourteen thousand) making over ten million four hundred thousand pages, giving the results of investigation and observation made by the station staff, have been issued.

In addition one thousand copies of our annual reports are forwarded to other stations and libraries. We have many calls for these reports from all parts of the United States that we cannot supply. As the publishing of this report is paid out of our current fund, it is not possible to print more than our exchanges demand.

WM. M. LIGGETT,
Director.

Printed also as Bulletin No. 53 of this Station.

EFFECTS OF THE ROTATION OF CROPS UPON THE HUMUS CONTENT AND THE FERTILITY OF SOILS.

HARRY SNYDER.

In the spring of 1892, a field that had been cultivated about forty years to small grains, was divided into six plots. The soil was in a fair condition as to fertility but had been somewhat exhausted by continuous wheat cropping. It was the plan to see what could be done to improve such a soil by a simple rotation of crops, and the use of farm manure.

The first year, 1892, all of the plots were sown to wheat in order to determine whether the soils were uniform in crop-producing power. The plots were found to be quite uniform, the greatest difference in yield between any two plots being 1.10 bushels of wheat per acre.

Before beginning the experiment, samples of soil were taken from each of the plots in the following way: Three points were selected in each plot. Within a radius of 20 feet from each of these points five samples of soil were taken with a post hole auger, to a depth of nine inches. All of these small samples were placed in a large box and thoroughly mixed and then the sample for analysis was taken from the mixed lot of small samples.

The plan of the experiment was to grow wheat, corn, oats, and barley continuously on four of the plots, and on two of the plots to raise these same crops in rotation with clover and manure. The crops raised on each plot were sampled and analyzed, and analyses were made of the soil before and after the experiment.

It is to be observed that on four of the plots there were no humus-forming materials added to the soil, while on two of the plots humus-forming materials were added.

The plots selected for these trials were quite uniform in

both chemical composition and crop producing power. No commercial fertilizers had ever been used. Prior to the wheat crop in 1892 corn had been grown. The land was well drained and in good mechanical condition. Plots 1, 2 and 3 were 4 rods by 5 rods, while plots 4, 5 and 6 were 2 rods by 5 rods. Each plot was separated from the next plot by a strip six feet wide. The plots were seeded to the centre of this six-foot strip, and at harvest time the outer edge of three feet around each plot, was cut away; this was done to avoid irregularities due to imperfect seeding and to the imperfect growth of the crop around the edges.

On plot No. 1, wheat was grown continuously. On plot No. 2, wheat was grown in 1893, and clover was sown with the wheat; a crop of clover was harvested in 1894. In the fall of 1894 the clover sod was plowed under, and the next year a crop of wheat was grown and in 1896 a crop of oats. It is the plan to apply manure at this point and produce a crop of corn, and to follow the corn with wheat and clover, the complete rotation being: (1) Wheat and clover, (2) clover, (3) wheat, (4) oats, (5) corn and manure.

Plot No. 3. After the wheat crop in 1892, oats were grown, and clover was seeded with the oats, and in 1894, a crop of clover was harvested. The clover sod was fall plowed and the next year barley was grown. After the barley crop the plot received 1200 pounds of manure, and the next year was seeded to corn, the complete rotation being: (1) Oats (and clover), (2) clover, (3) barley, (4) corn and manure.

On plot No. 4, corn is being grown continuously, while plots Nos. 5 and 6 produce oats and barley continuously.

Wheat Continuously.	Rotation.	Rotation.	Corn.	Oats.	Barley.
	1 Wheat (Clover)	1 Oats (Clover.)		Continuously	
	2 Clover.	2 Clover.			
	3 Wheat.	3 Barley.			
	4 Oats.	4 Corn and Manure.			
	5 Corn and Manure				

Before considering some of the chemical changes which have taken place in the soil, the yields per acre from the different plots will be briefly stated.

TABLE NO. 1.

Plot 1.			Plot 2.			Plot 3.		
		Bu. per Acre.			Bu. per Acre.			Bu. per Acre.
1893	Wheat	12.3	1893	Wheat	13.7	1893	Oats	46¼
1894	Wheat	8.9	1894	Clover (lbs.)	4320.	1894	Clover (lbs.)	2360.
1895	Wheat	17.3	1895	Wheat	22.	1895	Barley	42½
1896	Wheat	14.1	1896	Oats	31¼	1896	Corn	66.7
Plot 4.			**Plot 5.**			**Plot 6.**		
1893	Corn	50	1893	Oats	42½	1893	Barley	28
1894	Corn.	33⅓	1894	Oats	27	1894	Barley	18½
1895	Corn	75.5	1895	Oats	54.1	1895	Barley	39
1896	Corn	44.4	1896	Oats	31	1896	Barley	35⅔

[Note--In 1894 there was less than .2 inch rainfall from May 18 to Sept. 12.]

The Loss of Nitrogen.—In discussing the losses from the soil during these rotations, particular attention is given to the nitrogen because it is the most important element for grain production. It is an element that is capable of being lost from the soil more rapidly than any other element. It is the only element that is capable of being increased without the addition of some kind of fertilizer. The method for the determination of the total nitrogen is very accurate, which admits of a more general application of the results.

In these investigations four determinations of nitrogen were made with each sample. The original soils were analyzed at the time of sampling, kept in sealed bottles, and analyzed again along with the samples taken at the close of the rotation. Forty grams of soil were taken for each determination.

There is no element of the soil that requires more careful consideration at the present time than the element, nitrogen. It is the most expensive of all the elements. When purchased in the form of commercial fertilizers, it costs from 12 to 17 cents per pound.

The reason why the nitrogen of the soil decreases so rapidly is because it readily breaks loose from the humus (decaying vegetable and animal matter) with which it is combined and when separated from the humus it forms either gaseous products, like ammonia, or compounds known as nitrates, which are washed out of the soils by rains, or the nitrates may be lost by the workings of organisms which liberate the nitrogen as a gas.

In discussing these rotations it is not the intention to convey the idea that those given are the best that could be followed. This can be determined only after a long series of experiments upon different types of soil. Experiments relating to the various problems connected with the rotation of crops are now in progress at the Experiment Station.

The Loss of Nitrogen by Continuous Wheat Raising—In plots Nos. 1 and 2 there was originally present in the soil .221 per cent of nitrogen, equivalent to 5,400 lbs. of nitrogen per acre to a depth of 9 inches. After four years continuous cropping to wheat, plot No. 1 yielded .193 per cent of nitrogen, a loss of .028 per cent, equivalent to an aunual loss of 171 lbs. of nitrogen per acre. The amount of nitrogen removed in the crops during the four years amounted to 98 lbs. The difference between the amount lost from the soil and the amount removed in the crop was 146 lbs. per year. This nitrogen was lost by the oxidation of the humus, by denitrification, mechanically, by wind storms, and through the loss of nitrates by drainage. It is to be observed that for every pound of nitrogen removed in the wheat crop there has been a loss of over 5 lbs. of nitrogen from the soil.

In continuous wheat raising, without rotations or the use of manures, the decline in crop producing power is caused mainly by the excessive losses of nitrogen, not entirely on account of the nitrogen removed by the crop but because of the destruction of the humus. When the nitrogen is combined with the humus it is in a stable form, but as soon as the humus is destroyed the nitrogen is converted into gaseous and other forms which are readily lost. The continuous cultivation of small grains is particularly favorable to the destruction of both the humus and the nitrogen. The crop is unable to

utilize all of the nitrogen that is liberated by the breaking down of the humus. This change takes place during nearly eight months of the year, while the spring wheat crop takes its nitrogen from the soil in the spring and early summer when there is less decomposition of the humus taking place than later in the year. The wheat crop is placed at a disadvantage in obtaining its nitrogen. As shown in Bulletin No. 29, this station, the wheat plant takes over 85 per cent. of its nitrogen from the soil during the first fifty days of growth. The available nitrogen, as it is called, which is formed from the breaking down of the humus, if not utilized by a crop, is easily lost. Inasmuch as there is only this short period of fifty days when the nitrogen is mainly utilized by the wheat crop, while the breaking down of the humus goes on during seven or eight months of the year, it is easy to understand why there is such a heavy loss of nitrogen when a grain crop is raised continuously as on this plot.

The Gain of Nitrogen During a Rotation.—In plot No. 2 where clover has been grown in a rotation, there has been a gain of nitrogen. Originally the soil contained .221 per cent nitrogen. At the end of the rotation there was .231 per cent nitrogen present in the soil. On this plot clover was grown, and the second growth of clover was plowed under for green manure. The total nitrogen removed in the crops amounted to 178 pounds. Notwithstanding the fact that larger crops have been grown on this plot than on number 1 there has been a gain of 245 pounds of nitrogen in the four years' rotation, in addition to the nitrogen removed in the crops. This nitrogen, it is believed, has been gained largely by the clover from the free nitrogen of the air. Compared with plot number 1, this plot, after producing larger crops, contains much more nitrogen per acre; that is, when a rotation was followed, in which clover formed an important part, instead of a loss of nitrogen there was a gain.

In this rotation wheat was grown twice in five years. With the first wheat crop clover was sown. An unusually good catch was obtained, and the next year the first cutting of clover yielded over two tons per acre. The second crop,

which was nearly as heavy, was plowed under. The first year of the rotation, after the wheat was cut, the land, instead of being left bare, was covered with a good growth of clover, which not only prevented the loss of nitrogen and humus but added these valuable materials to the soil. When oats were grown in this rotation there was no material difference in yield from plot 5 where they were grown continuously. As is well known both oats and barley are not so delicate in feeding powers as wheat, and the soil had not been reduced below the point of good oat and barley production, as it had below the point of good wheat production.

It is to be observed, however, that when wheat followed clover the yield was five bushels more per acre than when wheat followed wheat, as in plot 1. The value of a good rotation is exemplified in this experiment where the yields per acre have been increased, and at the same time both the humus and the nitrogen have been increased.

On plot 3 a rotation somewhat similar to the one on plot 2 was followed. The first year clover was seeded with oats instead of with wheat as in number 2. The clover did not do so well as when seeded with the wheat; about a ton per acre less of clover was obtained from this plot. The second crop of clover was correspondingly light. In this rotation, where corn followed the second year after the clover, and received a light dressing of manure, a yield of 17 bushels per acre more of corn was obtained than when corn was grown continuously as on plot 4.

The soil of this plot originally contained .211 per cent of nitrogen. At the close of the rotation it contained .218 per cent of nitrogen. The amount of nitrogen removed in the crops during the four years amounted to 204 pounds. The gain in nitrogen has been at the rate of about 40 pounds per acre. The poorer stand of clover probably accounts for the smaller gain of nitrogen than in plot number 2. Had wheat been grown in this rotation instead of barley, there would, undoubtedly, have been a better return per acre.

The Loss of Nitrogen When Corn, Oats or Barley is Grown Continuously.—On plot No. 4 corn was grown continuously. The average yield per acre for the four years was 50.8 bushels. The soil originally contained .211 per cent nitrogen. After raising four corn crops the soil contained .197 per cent nitrogen, making a loss of 340 pounds. The nitrogen removed in the four corn crops amounted to 225 pounds, making an average loss of nearly 29 pounds of nitrogen per year not removed in the crop. Compared with the continuous wheat plot the loss of nitrogen from the corn plot has been materially less, but the loss is much greater than it should be. Many farmers have observed that when wheat follows corn the yield of wheat is increased. Although a corn crop takes more nitrogen from the soil than a wheat crop, the cultivation of the corn crop favors nitrification (production of nitrates from humus) and results in leaving more available nitrogen in the soil. Incidentally it may be said that growing corn between two wheat crops is not so hard on the land as bare summer fallow.

On this plot where corn was grown continuously it is to be observed that there has been a gradual annual decline of about 84 pounds of nitrogen per acre, 55 pounds being removed in the crop and about 29 pounds lost in other ways.

In plot number 5, where oats were grown continuously, there has been a more rapid decline of nitrogen than when wheat was grown continuously. During the four years there has been an annual loss of 196 pounds of nitrogen per acre. On an average, about 46 pounds of nitrogen per acre were removed in the oat crop. This difference of 150 pounds of nitrogen, between the amount lost from the soil and the amount removed in the crop, has been lost by the decomposition of the humus and in other ways as pointed out in discussing the losses from plot number 1. Although this soil has lost its nitrogen more rapidly than plot number 1, the yield per acre has not been affected so noticeably because the oat plant is a stronger feeding plant than wheat,

and it is capable of obtaining food from the soil where wheat would suffer for the want of food.

When barley was grown continuously, on plot number 6, the total loss of nitrogen from the soil was about the same as from plot 5, where oats were grown continuously. The soil of this plot originally contained .211 per cent nitrogen; after four years of barley, the soil contained .177 per cent nitrogen, equivalent to a loss of over 800 pounds of nitrogen in four years. The crop has removed about 30 pounds of nitrogen per year. When barley was grown continuously there was an annual loss of 170 pounds of nitrogen per acre in addition to the nitrogen removed in the crop.

The Increase and Decrease of Humus During the Rotations. —There has been a fluctuation of the humus content of the soil similar to the fluctuation of the nitrogen. Before the rotations, there was an average of about 3.30 per cent humus (decayed vegetable and animal matter), and 7.68 per cent of total volatile matter. At the close of the rotation periods the amounts of humus and volatile matter were as follows:

TABLE No. II—Loss and Gain or Humus.

	Humus Per Cent.	Gain † Loss *	Total Volatile Per Cent.	Gain † Loss *
Plot I. Wheat conti'usly...	3.00	*.30	7.48	*.20
Plot II. Rotation.....	3.80	†.50	8.05	†.37
Plot III. "	3.50	†.20	7.83	†.15
Plot IV. Corn continu'sly.	3.10	*.20	7.26	*.42
Plot V. Oats "	3.08	*.22	7.04	*.54
Plot VI. Barley "	3.10	*.20	6.87	*.81

In plot number 1 the loss of .30 per cent humus in four years is equivalent to a loss of 7300 pounds of humus. With continuous wheat raising there has been an annual loss of 1800 pounds of humus per acre. The losses from continuous corn, oats and barley cultivation have amounted to about 1500 pounds of humus per year.

In the rotation plots, instead of a loss of humus there has been a gain. In plot number three the gain of humus was equivalent to about 1500 pounds per acre.

The loss of humus from plots Nos. 1, 4, 5, and 6 has materially affected the physical qualities of the soil. Soil number one is a number of shades lighter than either numbers two or three. Number two is the darkest in the color. It would hardly be supposed that the loss of humus would affect the color of the soil. When the soils are arranged in order of color, numbers one, four, five and six are all about the same shade. Number three is materially darker, while number two is the darkest of all. Farmers who have seen the soils upon trays in the laboratory have invariably arranged them, as to color, in the order given.

There has also been a slight change in the weight of the soil. Originally the soils weighed about 75 lbs. per cubic foot. The weights per cubic foot at the close of the rotation were: No. 1, 76.9 lbs.; No. 2, 72 lbs.; No. 3, 74 lbs.; No. 4, 77.8 lbs.; No. 5, 76.9 lbs.; No. 6, 76.3 lbs. With the loss in humus it is to be observed that there has been a gradual increase in the weight per cubic foot of the soil.

In addition to the weight per cubic foot, and the color, there are other important physical changes which have occurred. The capacity for holding and retaining water has been affected. Determinations of moisture made during the growing season almost invariably gave a higher per cent of water from the rotation plots than from the plots where the grains have been grown continuously. This part of the subject is now under investigation and will be discussed in a future bulletin.

Rate of Oxidation of the Humus.—The losses of nitrogen from different kinds of soil undoubtedly vary to some extent. The greatest loss occurs when soils are rich in nitrogen, and the losses are proportionately less in soils which are poor in nitrogen. There is a tendency toward the establishment of an equilibrium as to the nitrogen content of soils. When a prairie soil is first brought under cultivation, the oxidation of the humus takes place rapidly. After the soils have been cultivated, and contain less humus, the oxidation of the humus goes on more slowly.

The figures given in this bulletin for the losses of nitrogen are probably much less than are the losses from many of the soils of the state that have been under cultivation for a shorter time, while for soils which are poorer in nitrogen than the experiment station soil, these figures are probably too high. It is with the new soils where the heaviest losses of nitrogen occur. Although the loss of nitrogen during the first few years is not felt, in time it will be severely felt.

Summer Fallowing Causes a Loss of both Humus and Nitrogen.—The practice of bare summer fallowing has been the cause of the unnecessary loss of nitrogen from many soils. Summer fallowing is practiced with the intention of increasing the yield of the crop which is to follow. The yield is increased, but it is at the expense of a loss of nitrogen. Summer fallowing leaves the soil in a good condition for nitrification to take place. The humus is used up more rapidly than if there were a crop on the land. The following crop is increased because there has been a larger portion of the humus broken down which has furnished available nitrogen for the next crop. While this change of the nitrogen from humus to available forms is very desirable, it must at times be prevented. In summer fallowing too much of the nitrogen is changed from the humic to available forms. The following crop can not utilize all of the nitrogen which has been liberated, and consequently there is a large per cent lost.

Adjoining plot No. 1 a strip of land was summer fallowed for two years. While it is not customary to follow two years in succession, fallowing is sometimes practiced every other year. In the soil before the summer fallowing there was present .221 per cent nitrogen, after two years of summer fallowing the soil contained .201 per cent nitrogen. While a loss of .02 of a per cent nitrogen does not appear to be a heavy one, it is in the aggregate quite large as it amounts to 590 pounds of nitrogen per acre. Two wheat crops would have removed less than a hundred pounds of nitrogen. In order to obtain available nitrogen for a wheat crop about five times more than is required is rendered available and lost.

The losses from summer fallowing a rich soil are greater than from fallowing a poorer soil because the oxidation of the humus is so much more rapid in the soils well stocked with humus. The question of summer fallowing should be carefully considered before it is practiced extensively because it temporarily increases the yield at the expense of permanently reducing the nitrogen content of the soil.

PRODUCTION OF HUMUS FROM MANURES.

HARRY SNYDER.

Nature of the Work.—In former publications from this station, experiments have been reported relating to the value of humus and the part which it takes in soil fertility. It has been thought best to repeat some of the experiments relating to the action of manures upon soils, and to the formation of humus from manures. While it is true that manure, green clover, meat scraps, straw, sawdust, or in fact almost any animal or vegetable matter, when it decomposes, may form humus, it does not necessarily follow that the humus is all equally valuable, or that all decomposing materials have the same power of uniting with the phosphoric acid and potash of the soil to form humates. In order to obtain information upon these various points, humus was prepared from a number of different materials.

Humus and Humates.—The animal and vegetable substances present in the soil, in intermediate forms of decomposition, are collectively spoken of as humus. Humus is a very complex material, composed of a large number of separate compounds about which but little is actually known. The decaying animal and vegetable substances are capable of uniting chemically with the potash, phosphoric acid and lime of the soil, forming compounds known as humates.

Former Work Relating to the Value of Humus—In former experiments, reported in bulletins No. 30 and 41, of this station, humus has been found to be valuable in the following ways:

1. The loss of humus from a soil involves a loss of nitrogen, one of the elements composing humus. Nitrogen is one of the most valuable elements found in the soil.

2. The loss of humus from the soil results in decreasing

its power of storing up and properly supplying crops with water. Soils containing a liberal supply of humus are capable of more effectually withstanding drought than similar soils with less humus.

3. The loss of humus has resulted in a decline in crop producing power due, not only to a loss of nitrogen and a decreased power of storing up water, but due also to a decrease of available potash and phosphoric acid.

4. When animal and vegetable matter, like manure, decomposes, the humus unites with some of the inert potash and phosphoric acid of the soil and forms a valuable class of compounds known as humates.

5. Many crops have the power of utilizing, for food purposes, the potash and phosphoric acid combined with the humus.

Importance of Humates.—If it is true that manures may unite with the potash, lime and phosphoric acid of the soil to form humates, then well prepared farm manure has an additional value and its value cannot be estimated on the same basis as commercial fertilizers that contain no humus-forming materials. Farm manures are valuable, not only for the plant food which they contain, but they are also valuable because they change the inert plant food of the soil into more available forms. Farm manures, by forming humates, take a very important part in imparting fertility.

Preparing the Humates.—The humates were prepared in the following general way: A weighed quantity of soil was mixed with a weighed quantity of green clover, then placed in a box and allowed to ferment and undergo humus formation for a year. The material in the box was protected from mechanical losses and leaching. The soil was practically free from humus. Analyses were made of both the soil, and the material used for humus production. After the humification process had been carried on for a year the material was weighed and analyzed. From the weight and composition of the materials, both before and after the process, the amounts of potash and phosphoric acid in the form of humates were determined. In many cases the humus produced contained more phosphoric acid and potash than was

originally present in the humus-forming material, plainly indicating that some of the phosphoric acid and potash of the soil had united with the humus.

Description of Soil Used in the Experiments.—The soil used in these experiments contained only .06 of a per cent of humus. It was obtained at a depth of about 20 feet from the surface of the ground from an excavation that had been made for a building. The soil was composed of about 40 per cent of fine and very fine sand, 50 per cent of silt, mostly fine silt, and nearly 10 per cent of clay-like particles. The soil contained 0.52 per cent potash, 0.26 per cent phosphoric acid, and 0.90 per cent lime. The soil was in a good mechanical condition, and was very similar to many of the prairie subsoils of the state, commonly spoken of as clay subsoils. Although the amount of plant food present in this soil was high, the soil produced only a few sickly plants. The soil was what might be termed of good mechanical structure, and rich in total plant food, but not present in available forms. Various humus-forming materials, as cow manure, green clover, sawdust, meat scraps, straw, sugar, flour, etc. were used to determine to what extent a chemical union with this inert phosphoric acid and potash of the soil could be effected. These experiments are given in detail.

Experiment No. 1. Humus from Cow Manure.—Six pounds of soil (2718 grams) and 1 pound of fresh cow manure were thoroughly mixed and placed in a box. The box was tight to prevent drainage, and the cover was so constructed as to admit air and at the same time keep out foreign material. The box containing the soil and manure was placed in the ground so that the top was just a little above the surface of the ground. The box was left in the soil from Aug. 2, 1895, to Aug. 2, 1896. At the end of the year the soil and manure weighed about 6¼ pounds (2818 grams dry matter.)

The following table gives the composition of the original soil, the manure and the final product of soil and manure:

TABLE NO. III.

	Original Soil.	Manure.	Final Product Soil and Manure.
	Per Cent.	Per Cent.	Per Cent.
Total Nitrogen.....	.02	.40	.....
Humic Phosphoric Acid.....	.01	.201	.057
Humic Potash.....	.006	.201	.045
Humus.....	.06	.....	.58

All of the phosphoric acid and potash of the manure are considered as humus-forming materials. The humus represents the soluble organic materials which are extracted with a two per cent solution of ammonia, after treating the soil with a dilute solution of hydrochloric acid. The humic phosphoric acid and potash represent the phosphoric acid and potash present in the humus extractive material. The figures for the humic phosphoric acid and potash are given as percentage amounts of the total soil.

By multiplying the percentage composition by the total weight, the total amount of humic phosphoric acid and potash are obtained.

TABLE No. IV.

	Original Soil and Manure. Grams.	Final product of Soil and Manure. Grams.	Gain. Grams.
Humic phosphoric acid.....	1.17	1.62	.45
Humic potash.....	1.06	1.27	.21

In this experiment, one pound of fresh cow manure acting on six pounds of soil has resulted in changing nearly half a gram of phosphoric acid and a fourth of a gram of potash from mineral to humate forms. This is equivalent to a gain of over 55 per cent of phosphoric acid and 50 per cent of potash. At the same rate a ton of manure would combine with about 2.2 pounds of the inert phosphoric acid of the soil in one year.

The humus materials obtained with a dilute potash

solution were subjected to a combustion analysis, and were found to have the following ultimate composition, calculated on the basis of the ash free material:

	Per cent.
Carbon	41.95
Hydrogen	6.26
Nitrogen	6.16
Oxygen	45.63
Total	100.00

In a similar experiment, reported in bulletin No. 41, when a hundred pounds of soil and twenty pounds of manure were allowed to undergo fermentation for one year, the gains were as follows:

TABLE NO. V.

	Total Humates in Soil Originally.	Total Humates in Soil, After 12 Months, Less Humates of Manure.	Gain.
	Grams.	Grams.	Grams.
Potash	7.25	9.14	1.89
Soda	7.84	10.11	2.27
Iron	2.44	4.13	1.69
Magnesia	.35	.54	.19
Aluminia	2.96	4.64	1.68
Phosphoric Anhydrid	11.97	13.99	2.02

The gain in phosphoric acid was equivalent to seventeen per cent, and of potash to twenty-six per cent of the original amounts present in the soil in humic forms.

Experiment No. 2. Humus from Green Clover.—In this experiment, twenty pounds of soil (9060 grams) and a pound and a half of fine cut clover (227 grams, dry matter) were used. The box containing the mixed soil and clover was placed near the box in the first experiment. At the end of the year the box contained 9137 grams of dry matter. The green clover underwent very rapid fermentation; at the end

of the year the 227 grams of dry matter decreased to 77 grams, a loss of 70 per cent.

TABLE No. VI.

	Original Soil.	Clover.	Soil and Clover.
	Per Cent.	Per Cent.	Per Cent.
Total Nitrogen	.02	3.01	.088
Humic phos. acid	.01	1.02	.041
Humic potash	.006	2.08	.054
Humus	.06	.....	.37

The grams of humic phosphoric acid and potash obtained by multiplying the weight by the percentage composition, are as follows:

TABLE No. VII.

	Original Soil and Clover, Grams.	Final Product of Clover, and Soil, Grams.	Gain. Grams.
Humic phosphoric acid	3.21	3.74	.53
Humic potash	5.26	4.93	.33 (loss)

In this experiment the pound and a half of green clover acting on twenty pounds of soil have changed about half of a gram of the more inert soil's phosphoric acid into the more valuable humic forms. At the same rate one ton of green clover would change 1.5 pounds of phosphoric acid to humic forms. The experiment shows a loss of potash. The green clover was very rich in potash, and the humus that was formed was not able to hold in chemical combination all of the potash originally present in the plant. The fermentation of the green clover had been very rapid and quite complete; it had probably been carried beyond the point of humic production and had reached the point of humic decomposition.

The ultimate composition of the green clover humus was as follows:

	Per cent.
Carbon	54.22
Hydrogen	3.40
Nitrogen	8.24
Oxygen	34.14
Total	100.00

Green clover gives a very concentrated humus, rich in nitrogen, phosphoric acid and other elements of plant food. With the exception of the meat scraps, the green clover produced a humus the richest in nitrogen of any of the organic materials used in these experiments.

Experiment No. 3. Humus from Meat Scraps.—Seven pounds of soil (3175 grams) and about 5 ounces (150 grams) of meat scraps were thoroughly mixed, placed in a box, as in the preceding experiments, and exposed for one year, when the contents of the box weighed 3270 grams. The composition of the soil, of the meat, and of the final product of soil and meat are all given in the following table:

TABLE No. VIII.

	Original Soil.	Meat.	Final Product of Soil and Meat.
Total Nitrogen	.02	4.10	.....
Humic phosphoric acid	.61	.50	.036
Humic potash	.006	.04	.011
Humus	.06	.....	.31

TABLE No. IX.

Total amounts in Grams in:

	Original Soil and meat.	Final Product of Soil and Meat Scraps.	Gain.
Humic phosphoric acid	1.07	1.18	.12
Humic potash	.25	.36	.11

In this experiment the five ounces of meat scraps, acting on twenty pounds of soil, changed about a tenth of a gram of both phosphoric acid and potash into humic forms, which is a gain of about ten per cent of phosphoric acid and thirty per cent of potash. The humus produced by the meat scraps was very concentrated, being particularly rich in nitrogen, as the following proximate analysis will show:

	Per cent.
Carbon	48.77
Hydrogen	4.30
Nitrogen	10.96
Oxygen	35.97
Total	100.00

Experiment No. 4. Humus Produced by Flour.—In this experiment about six pounds of soil (2720 grams) and 225 grams of flour were used. The flour and soil, after mixing, were placed in a box and were allowed to ferment for one year, when the final product weighed 2845 grams. The composition of the flour, of the soil, and of the final product of soil and flour, as well as the total amounts in grams, are all given in tabular form.

TABLE No. X.

	Soil.	Flour.	Final Product of Soil and Flour.
	Per Cent.	Per Cent.	Per Cent.
Total Nitrogen	.02	1.70	.094
Humic phosphoric acid	.01	.15	.025
Humic potash	.006	.07	.017
Humus	.06	.....	.47

TABLE No. XI.

	Original Soil and Flour	Final Product of Soil and Flour.	Gain
	Grams.	Grams.	Grams.
Humic phosphoric acid	.61	.71	.12
Humic potash	.32	.46	.14

The humus produced by the flour had the following ultimate composition:

	Per Cent.
Carbon	51.02
Hydrogen	3.82
Nitrogen	5.02
Oxygen	40.14
Total	100.00

This experiment indicates that flour produces a humus with a fair amount of nitrogen, and that in the production of the humus, half a pound of flour, acting on the six pounds of soil, has changed over a tenth of a gram of both phosphoric acid and potash into humic forms.

Experiment No. 5. Humus from Asparagin.—Asparagin was taken as a type of an amide compound. Seven pounds of soil (3175 grams) and about ⅓ of an ounce of asparagin (10 grams) were mixed, placed in a box, and allowed to act for one year. From the analysis there was no evidence that the asparagin had entered into humic forms or had caused any change in the forms of the soil potash and phosphoric acid.

Experiment No. 6. Humus from Oat Straw.—Fifteen pounds of soil (6,777 grams) and five ounces of fine cut oat straw were carefully mixed, and placed in a box, as in the other humus culture experiments and left for one year. At the end of the year the pieces of straw did not appear to have undergone any fermentation changes. The mixed straw and soil weighed finally 6,875 grams. The composition of the soil, of the straw and of the final product of soil and straw was as follows:

TABLE No. XII.

	Original Soil.	Straw.	Final Product of Soil and Straw.
	Per cent.	Per cent.	Per cent.
Total Nitrogen	.02	.50	.031
Humic phosphoric acid	.01	.22	.015
Humic potash	.006	.90	.035
Humus	.06		.46

TABLE No. XIII.

	Original Soil and Straw. Grams.	Final Product of Soil and Straw. Grams.
Humic phosphoric acid	1.02	1.03
Humic potash	2.42	2.41

In this experiment there was evidently no combination of the potash and phosphoric acid of the soil with the humus formed from the straw. The straw was very slow in fermenting and although capable of forming humus, the humus that was produced did not combine with the phosphoric acid and potash of the soil; this is probably due to the slow rotting of the straw. If a longer time had been allowed for decomposition the results might have been more favorable. Straw is capable of forming humus but the humus produced was poorer in nitrogen than the humus formed by manure, green clover, or meat scraps, but it is a richer humus than that formed from sawdust, starch or sugar.

The humus from oat straw was found to have the following ultimate composition:

	Per cent.
Carbon	54.30
Hydrogen	2.48
Nitrogen	2.50
Oxygen	40.72

Experiment No. 7. Humus from Sawdust.—Inasmuch as sawdust is so frequently used as an absorbent in stables, it was thought best to include it as one of the materials in this test of humus-forming substances. Ten pounds of soil (4530 grams) and half a pound of sawdust were mixed, placed in a tight box and left for a year to ferment. At the end of the year the sawdust appeared in nearly the same physical condition as at the beginning. The final weight of the sawdust and soil was 4705 grams. The composition, and final amounts are given in the following tables:

TABLE No. XIV.

	Soil.	Sawdust.	Final Product Soil and Sawdust.
	Per cent.	Per cent.	Per cent.
Total Nitrogen	.02	.09	.023
Humic phosphoric acid	.01	.15	.018
Humic Potash	.006	.21	.014
Humus	.06		.59

TABLE No. XV.

	Soil and Sawdust.	Final Product Soil and Sawdust.
	Grams.	Grams.
Humic phosphoric acid	.79	.85
Humic potash	.64	.66

In this experiment the gains are too small to consider, being less than duplicate analysis of the same sample would show, except possibly in the case of the phosphoric acid. The analyses show that there has been practically no union of the potash and phosphoric acid of the soil with the humus produced by the sawdust. About twenty per cent of the sawdust has fermented without forming humates, although about half a per cent of humus has been formed. The composition of the humus from the sawdust was found to be:

	Per cent.
Carbon	49.28
Hydrogen	3.33
Nitrogen	.32
Oxygen	47.07
Total	100.00

The humus from sawdust is rich in carbon, but is very poor in nitrogen, phosphoric acid and potash.

Experiment No. 8. Humus From Sugar.—Seven pounds of soil (3171 grams) and half a pound of sugar (225 grams) were thoroughly mixed, and left in a box, for one year.

At the end of the year there was but little of the sugar that remained; the soil and sugar weighed 3220 grams.

TABLE No. XVI.

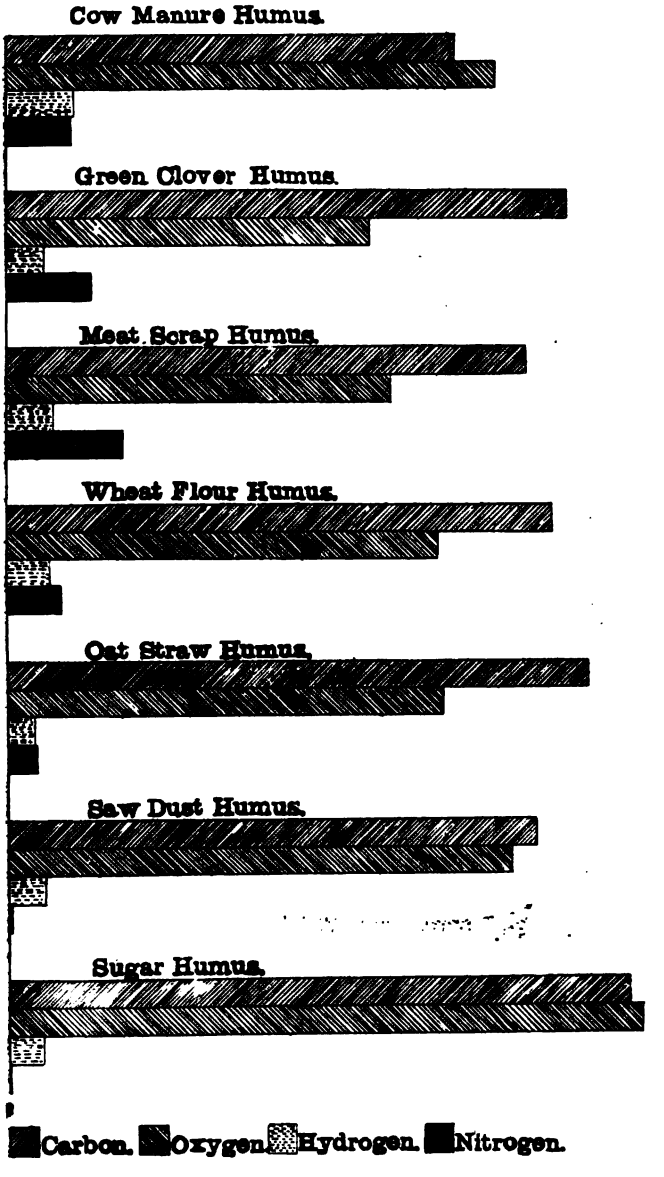
	Composition of the Soil.	Sugar.	Final Product of Soil and Sugar.
Total Nitrogen	.02		.018
Humic phosphoric acid	.01		.01
Humic potash	.006		.005
Humus	.06		.32

The final composition of the soil and sugar is nearly the same as the composition of the original soil, the differences being less than the usual errors of chemical analysis. There is no evidence that the sugar, in its fermentation is capable of uniting with the potash and phosphoric acid of the soil, and producing humates.

The humus formed from sugar contained only a trace of nitrogen, which probably came from the small amount of nitrogen and humus in the soil, but the sugar humus was rich in carbon, as shown by the following ultimate analysis:

	Per Cent.
Carbon	57.84
Hydrogen	3.04
Nitrogen	.08
Oxygen	39.04
Total	100.00

Variations in the Composition of Humus.—There is a marked variation in the composition of the humus produced from the different kinds of organic materials. The straw, sawdust and sugar each yielded a humus characteristically rich in carbon and poor in nitrogen. The humus from these materials did not exhibit any marked tendency or power to unite with the potash and phosphoric acid of the soil to form humates. On the other hand, materials like cow manure, green clover and meat scraps, substances which are rich in


Cow Manure Humus.
Green Clover Humus.
Meat Scrap Humus.
Wheat Flour Humus.
Oat Straw Humus.
Saw Dust Humus.
Sugar Humus.
Carbon. Oxygen. Hydrogen. Nitrogen.

nitrogen, produce a more valuable humus which is rich in nitrogen, phosphoric acid and potash, and the humus which is produced is able to combine with the potash and phosphoric acid of the soil to form humates. There may, however, be a great difference in the power which soils possess to form humates. The variations in the composition of humus produced by different organic substances are best observed when the analyses are arranged in tabular form.

TABLE No. XVII.—Humus Produced by—

	Cow Manure.	Green Clover.	Meat Scraps.	Wheat Flour.	Oat Straw.	Sawdust.	Sugar.
Carbon.....	41.95	54.22	48.77	51.02	54.30	49.28	57.84
Hydrogen....	6.26	3.40	4.30	3.82	2.48	3.33	3.04
Nitrogen.....	6.16	8.24	10.96	5.02	2.50	.32	.08
Oxygen.....	45.63	34.14	35.97	40.14	40.72	47.07	39.04
Total.....	100.	100.	100.	100.	100.	100.	100.

TABLE No. XVIII.

	Highest.		Lowest.		Difference.
Carbon.....	57.84	Sugar	41.95	Cow manure.	15.89
Hydrogen.....	6.26	Cow manure.	2.48	Oat straw.	3.78
Nitrogen.....	10.96	Meat scraps.	0.08	Sugar.	10.88
Oxygen.....	47.07	Sawdust.	34.14	Green clover.	12.93

The differences in composition are noticeable. The humus produced by each material as green clover, oat straw or sawdust is different from the humus produced by every other material. The humus from a material as green clover is undoubtedly very complex in nature. Inasmuch as the green clover contains both nitrogenous and non-nitrogenous compounds, and as each class of compounds has a different action in humification processes, it follows that the humus from the green clover must be a mixture of both nitrogenous and non-nitrogenous humic products.

The nature of the humus, whether nitrogenous or non-nitrogenous, is important. The humus produced from sawdust and meat scraps may be taken as an example.

In the soil containing the sawdust, .59 per cent of humus was produced, while the meat scraps produced .31 per cent humus. The sawdust produced a larger quantity of humus than the meat scraps. The humus from the sawdust contained .31 per cent of nitrogen, while the humus from the meat scraps contained 10.96 per cent nitrogen. The sawdust produced a larger quantity of humus poor in nitrogen, while the meat scraps produced a smaller amount of humus rich in nitrogen.

Classification of Humus Compounds.—There appears to have been no classification of the humus compounds proposed since the classification of Mulder, in 1840, into humin, ulmin, humic, ulmic, crenic and approcrenic acids, as follows:

TABLE No. XIX

	Ulmin and Ulmic acid.	Humin and Humic acid.	Crenic acid.	Approcrenic acid.
	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	67.1	64.4	44.0	34.4
Hydrogen	4.2	4.3	5.5	3.5
Oxygen	28.7	31.3	46.6	39.1
Nitrogen	0.0	.....	3.9	3.0

Humic and ulmic acids are given as containing no nitrogen, while crenic and approcrenic acids are given as containing 3.9 and 3.0 per cent, respectively of nitrogen. None of the humus compounds in these culture experiments have the same composition as those given by Mulder. The sawdust and sugar approach in composition the nearest to the humic and ulmic acid formulas, while oat straw comes the nearest to crenic and approcrenic acids. The differences are, however, great.

It would seem best, in the present state of our knowledge of the humus compounds, to make the division on the basis of the nitrogen content, that is divide the humus compounds into classes as follows:

1. Non-nitrogenous group, as sugar humus.
2. Humus containing 1 to 2 per cent nitrogen as sawdust humus.

3. Humus containing 2 to 4 per cent nitrogen as oat straw humus.

4. Humus containing 4 to 8 per cent nitrogen as flour, and cow manure.

5. Humus containing over 8 or 9 per cent nitrogen.

Such a division would give an approximate idea as to the nature of the material from which the humus has been produced, as well as an approximate idea of its agricultural value. As ordinarily used the term humus is a very indefinite one, as far as conveying any idea of the chemical composition or agricultural value of the compounds for which it stands.

The humate compounds do not form well defined crystallized bodies and it is almost impossible to obtain any one of these compounds in a pure state to study the structural composition.

Composition of Humus Obtained from Old and New Soils.—A prairie soil that had never been under cultivation contained 5.30 per cent humus. A sample of similar soil from an adjoining field that had been continuously cultivated for several years to small grains, contained 3.38 per cent humus. The humus from each soil when subjected to an ultimate analysis gave the following results:

TABLE No. XX.

	Humus from new Soil.	Humus from old Soil.
	Per cent.	Per cent.
Carbon	44.12	50.10
Hydrogen	6.00	4.80
Oxygen	36.16	33.66
Nitrogen	8.12	6.50
Ash	6.60	4.90

These results show the extent to which the humus is changed when new land is brought under cultivation. In the long-cultivated soil the humus contains more carbon and holds less nitrogen and mineral matter in chemical combina-

tion than in the new soil. In the ten years' cultivation the humus has materially changed in composition, it has been converted into a less active state, and contains a larger proportion of carbon, due to the more rapid oxidation of the nitrogen and hydrogen and to the slower oxidation of the carbon.

Influence of Different Methods of Farming Upon the Humus Content of the Soil.—The general system of farming that is followed has a direct influence upon the amount of humus in the soil. Similar soils from the same and from adjoining farms that have been cropped differently, show important differences, not only in the amount of humus present, but in the per cent of nitrogen, and the amount of phosphoric acid combined with the humus. These differences are given in the following table:

TABLE No. XXI.—Influence of Different Systems of Farming upon the Chemical and Physical Properties of Soils.

Character of Soil.	Weight per cu. foot	Humus	Nitrogen.	Phosphoric acid combined with Humus.	Water holding capacity.
	lbs.	per cent.	per cent	per cent.	per cent.
1 Cultivated 35 years; rotation of crops and manure; high state of productiveness.	70	3.32	.30	.04	48
2 Originally same as 1; continous grain cropping for 35 years; low state of productiveness...	72	1.80	.16	.01	39
3 Cultivated 42 years; systematic rotation and manure; good state of productiveness	70	3.46	.26	.03	59
4 Originally same as 3; cultivated 35 years; no systematic rotation or manure; medium state of productiveness	67	2 45	.21	.03	57

[Reported in Year Book U. S. Dept. Agr. 1896.]

Soils Nos. 1 and 2 are from two adjoining farms, and originally had practically the same crop-producing power, No. 1 has received regular and liberal dressings of manure, and has produced wheat, corn, oats, timothy and clover in rotation. There has been no apparent decline in fertility. No. 2 has been under continuous grain cultivation and has never received any farm manure or other humus-forming ma-

terials. During the first few years heavy crops of wheat were raised, but during the past few years the yield has been very low, especially in dry seasons. The land has been reduced in wheat producing power from 25 to 8 bushels per acre.

The main difference between the two soils at the present time is in the amount of humus, nitrogen and humic phosphoric acid.

Soils Nos. 3 and 4 are from the same farm. No. 3 has been cropped forty-two years, timothy and clover, wheat, oats and corn having been raised in rotation. Every five years the land has received 10 tons of stable manure per acre. No. 4 has been cropped only thirty-five years, producing mainly wheat, oats and corn, with an occasional crop of timothy. It has not been cropped continuously to one crop, neither has it been under a regular system of rotation. The soil which has been cropped forty-two years shows more humus and nitrogen than the one which has been cropped thirty-five years.

Destruction of Humus by Forest Fires.—The losses of humus and nitrogen by forest fires are frequently very heavy. When the soil is of a sandy nature, and the fire is severe, from 50 to 75 per cent of both nitrogen and humus may be destroyed. A sample of soil, No. 228, taken near Hinckley in 1893, (the analysis of this soil is reported in bulletin No. 30, page 182,) a year prior to the great forest fire of 1894, showed 1.69 per cent humus, and .12 per cent nitrogen. After the forest fire, a similar sample from the same field showed .41 per cent humus and .03 per cent nitrogen. The loss of nitrogen from this soil amounted to 2500 pounds per acre.

Another sample of soil, No. 418, from Staples, Todd county contained 1.52 per cent humus and .12 per cent nitrogen. A similar soil from an adjoining field, No. 424, that had been burned over and left as waste land, contained .47 per cent humus .04 per cent nitrogen.

The excessive losses of nitrogen and humus, caused by forest fires, greatly decrease the agricultural value of the land. While it is true that good crops may be obtained from

such lands for two or three years, due to the ashes that have been formed, the soils soon show signs of nitrogen hunger, and become unproductive. The loss of nitrogen and humus is more severely felt on the sandy soils, than on the clay soils. In the forest soils there is not an over abundance of nitrogen, and if 75 per cent is destroyed by a forest fire it leaves the soil in a poor condition as to nitrogen.

Prairie fires have not been so destructive upon the humus as the forest fires, because the burning has been confined more to the surface. An average prairie fire will, however, remove more nitrogen from the soil than five ordinary crops of wheat.

In the clearing of new land, particularly forest land, there is frequently an unnecessary destruction of humus forming materials. Instead of burning all of the vegetable matter it would be better economy to leave some in piles for spreading at a future time. By this means the soil would be kept in better condition for a longer time.

Soils in Need of Humus.—Soils that are the most in need of humus are the sandy and sandy loam soils that have been cultivated for a number of years to corn, potatoes and small grains, without the use of stable manures or the proper rotation of crops. There are many soils of the state that could be improved by the addition of humus materials. A clay soil, as a rule, does not stand in need of humus so much as a loam soil or a sandy soil. Alkali soils are usually deficient in humus. The addition of humus materials to a loam or sandy soil is beneficial in preventing the soil from "drifting" during heavy wind storms, because humus binds the soil particles together more firmly. There are but few soils, under ordinary cultivation, to which it is not safe to add humus-forming materials.

Soils Not in Immediate need of Humus.—Ordinary prairie soils, for the first ten years after breaking, are usually well supplied with humus. Swampy, peaty, and muck soils contain large amounts of humus. If the soil is sour to the taste, the humic acid may be neutralized by a dressing of lime or wood ashes. Soils from poorly drained places frequently contain sour humus. Very frequently, muck soils

are deposited over marl beds. Marl, which is a mixture of limestone and clay, may be used as a top dressing for the muck soils. There is but little danger, however, from the formation of sour humus in the soils of this state, because, as a rule, the soils are well supplied with lime, which combines with the humus and prevents the formation of the sour humus.

It is not advisable to burn over low peaty places. A soil containing as high as seventy per cent of vegetable matter may be brought under cultivation and converted into meadow land. A soil containing about fifty per cent of vegetable matter may be converted into what is generally termed a permanent meadow. Soils of this type have produced hay for forty years without any decline in crop producing power.

While humus is a very important factor in imparting fertility to a soil, it must be remembered that it is possible to go to the other extreme and have too much humus in the soil or to get the humus in the undesirable form of sour mould.

In localities where the rainfall is evenly distributed during the year, the necessity for maintaining the humus is not so severely felt as in localities where the rainfall is not so evenly distributed. As pointed out in former bulletins the humus takes an important part in aiding a soil to retain water and withstand drought.

Mineral Matter Combined with Humus.—As ordinarily obtained from the soil, humus contains a high per cent of mineral matter. Not all of the mineral matter extracted with the humus is in chemical combination with the humus. If the humus solution is neutralized with an acid, a floculent percipitate, known as humic acid, is obtained. It seems reasonable to assume that the mineral matter which is obtained from the precipitated humus material is in combination with the humus. If it were not in combination it would have been removed in either the dilute acid, alkali or the water used for washing the material and it would not have been reprecipitated.

TABLE No. XXII.—Mineral Matter Combined with the Humus.

	Sample Composed of 20 Soils.	In Eight Soils. (Former Analyses)
Silica	51.75	61.97
Potash	12.02	7.50
Soda	2.48	8.13
Lime		.09
Magnesia	3.26	.36
Ferric Oxide	5.12	3.12
Aluminia	3.72	3.48
Phosphoric Anhydrid	21.55	12.37
Sulphuric "	1.25	.98
Carbonic "		1.64

It appears that over half of the ash of the precipitated humus material is silica, while over twelve per cent, and in some cases as high as 20 per cent, is phosphoric acid. The potash content ranges from 7.50 to 12 per cent.

A rich prairie soil containing 3.50 per cent of precipitated humus materials, will contain over 100,000 pounds per acre of pure humus. The average per cent of ash in the pure humus is rarely less than seven. On a basis of 10 per cent there would be 10,000 pounds of mineral matter combined with the humus of which over 12 per cent is phosphoric acid and over seven per cent is potash, equivalent to over 1200 pounds per acre of humic phosphoric acid and 750 pounds of humic potash. Many soils contain even more than these amounts.

After fifteen or twenty years' continuous grain cultivation the per cent of total humus is usually reduced by half and the humic phosphoric acid is reduced by more than half. While the total amount of phosphoric acid and potash removed in the twenty grain crops has not been large compared with the total amount in the soil, the amount combined with the humus has been materially reduced. Twenty wheat crops averaging 18 bushels per acre will remove about 400 pounds of phosphoric acid. Average prairie soil

contains about 8700 pounds of phosphoric acid per acre to the depth of one foot. When the soil is first brought under cultivation, about 1500 pounds of this 8700 are combined with the humus. After twenty years' grain cultivation, the soil will still contain over 8000 pounds per acre of total phosphoric acid, but instead of 1500, there is only about 400 pounds combined with the humus.

It seems reasonable to suppose that this change of phosphoric acid from humic to less soluble forms has been an important factor in making the soils less productive.

It is not intended to convey the idea that the humic phosphoric acid is the only form of phosphoric acid that is of value to crops, because there are soils that contain but little humic phosphoric acid and yet appear to be well supplied with available phosphoric acid. Humic phosphoric acid is, however, one of the most valuable forms of available phosphoric acid.

SUMMARY NOTES.

1. When wheat was grown continuously on the same plot there was an annual loss of 171 pounds of nitrogen per acre. About 25 pounds were removed by the crop while 146 pounds per acre were lost from the soil by the wearing away of the humus.

2. When wheat was grown in a rotation, after clover, there was a yield of five bushels per acre more of wheat than when grown continuously. When manure was used and clover was grown there was a gain of nitrogen, and at the same time larger yields were obtained. When corn was grown in a rotation, it yielded 17 bushels per acre more than when it was grown on the same plot continuously.

3. When corn, oats, or barley was grown continuously on the same plot and no manure used, there was an annual loss of from 80 to 200 pounds of nitrogen from the soil, the larger portion of which was not carried away in the crop, but was lost by the destruction of the humus. The annual loss per acre of humus when wheat, corn, oats or barley was grown continuously ranged from 1,500 to 1,800 pounds.

4. A loss of humus from the soil has made the soils lighter colored, caused them to weigh more per cubic foot and has reduced the power of the soil to store up water.

5. When summer fallowing is extensively practiced the yield of the following crop is increased at the expense of rendering five times more nitrogen available than is required by the crop. The available nitrogen, if not utilized by the crop, is not stored up in the soil but is lost.

6. Cow manure, green clover and meat scraps produce valuable forms of humus, rich in nitrogen. The humus produced is capable of combining with the phosphoric acid and potash of the soil to form humates.

7. Sawdust, straw and carbohydrates, as sugar, produce a humus rich in carbon. This humus has less power to

combine with the phosphoric acid and potash of the soil, than humus formed from materials richer in nitrogen.

8. The humus from soils which have been cropped for a series of years contains less nitrogen and mineral matter, and more carbon than the humus from soils that have not been cultivated.

9. Forest fires may cause a loss of 75 per cent of the total nitrogen of the soil. The practice of burning over new land is sometimes carried to such an extent as to injure the permanent crop producing power.

10. Soils which stand in need of humus are sandy and sandy loam soils which have been cultivated a number of years to corn, potatoes and small grains, without the use of stable manures or the proper rotation of crops.

11. A prairie soil before it is brought under cultivation will contain about 1,500 pounds of phosphoric acid and about 800 pounds of potash per acre combined with the humus. After twenty years of cultivation, if the humus is not kept up, there will be about 400 pounds of phosphoric acid combined with the humus.

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HUMAN FOOD INVESTIGATIONS.

THE GLUTEN OF WHEAT.

HARRY SNYDER.

Nature of the Work.—As is well known, there is a great difference in both the food value and the bread making qualities of flour made from different grades of wheat. With the object of determining, as far as possible, the cause of this difference in food value and bread making qualities, samples were obtained of wheat grown in Russia, India, Chili, and Argentine Republic, as well as of spring and winter wheat grown in different parts of the United States.

It was found that the main difference, in the various samples, was in the gluten. There was a difference, not only in the amount of gluten present, but also in the character of the gluten. Two samples of flour containing the same amounts of gluten frequently have entirely different bread making qualities, due to the peculiar composition of the gluten. The gluten of wheat is usually understood to be that part which remains after removing the starch by washing the flour or meal, after it has been made into a dough, with cold water. In the work reported in this bulletin the gluten was obtained by chemical methods.

Composition of Wheat Gluten.—The gluten of wheat is composed of two parts. One of the substances resembles gelatine, and is called gliadin. It is the gliadin which binds together the flour particles to form a dough. Gliadin has been called plant gelatine. The gliadin, by binding together the particles of flour, enables the dough to retain the gas and to become light when the bread is raised. A certain amount of gliadin, or binding material, in a flour is essential;

an excessive amount may cause a flour to form a soft sticky dough and produce a poor quality of bread.

In addition to the gliadin, or binding material, gluten also contains a substance called glutenin, which can be obtained in the form of a fine white powder. The glutenin "serves as a nucleus to which the gliadin adheres," and it prevents the dough from becoming soft and sticky; that is, the glutenin is the material to which the gliadin attaches itself. It is to be observed that the two bodies which compose the gluten of wheat when present in the right proportions aid each other in forming a good gluten for bread making purposes.

As previously stated two samples of wheat may contain the same amount of gluten; the flour from one of the wheats may produce good bread, while the flour from the other wheat may produce bread of very poor quality. In the first wheat sample, the gliadin and glutenin are present in the right proportions to form a good gluten, while in the second wheat the gliadin and glutenin are not present in the right proportions,—there is an excessive amount of either gliadin or glutenin. An excessive amount of gliadin and a small amount of glutenin make a soft, sticky dough. An excessive amount of glutenin and a small amount of gliadin prevent the gas from being retained, and the bread from becoming light.

The gluten of wheat constitutes from 80 to 85 per cent of the total wheat proteids, which are the important muscle forming and vital nutrients. For food purposes, wheat should contain a high per cent of protein. For bread making purposes the gluten should be well balanced, that is, contain the right proportion of gliadin (binding material) to glutenin. The most valuable wheats for both food and bread making purposes are those rich in protein, of which 80 to 85 per cent is gluten, and the gluten is composed of about 60 per cent gliadin and about 40 per cent glutenin. A wheat may produce a good quality of bread and at the same time the bread may possess a relatively low value as food on account of not containing a sufficient amount of protein. On the other hand a wheat may possess poor

bread making qualities and still contain a high per cent of protein. That is, good bread making qualities in a wheat are not always indicative of high food value.

The Gluten from Different Types of Wheat.—In the table, the names of the samples and the sources from which they were obtained are first given. The protein includes the gluten and about 20 per cent of other proteid bodies which do not form a part of the gluten. Gluten represents the sum of the gliadin and glutenin as obtained by chemical analysis. The gliadin was obtained by extracting the fine wheat meal with 70 per cent alcohol. The glutenin was obtained by extracting the meal with potash lye after first removing all other proteids.

Samples Nos. 1, 2 and 6 were grown on the University farm. The other samples were obtained through the State Railroad and Warehouse Commission from the places indicated. All of the samples were selected as being the best types which could be obtained.

Comparisons from a limited number of analyses are not so satisfactory as comparisons from a large number, but the qualities of the various wheat samples bear out so well the properties of the gliadin and glutenin bodies that it is very evident that the qualities of the flour are materially influenced by the amount of gliadin and glutenin present in the gluten. This work has been duplicated with flour from different grades of wheat.

In samples Nos. 1 and 2, which may be taken as good types of northern grown hard spring wheat, the gluten contains about 60 per cent gliadin (binding material) and 40 per cent glutenin (material for the gliadin to adhere to). In the so called soft wheat as Nos. 6, 9, and 13, there is from 7 to 13 per cent more of gliadin and a correspondingly less amount of glutenin. It is to be observed that in samples Nos. 1, 2 and 6 the highest amounts of protein are found. The Indian and Chili wheats contain a very low per cent of protein, and the gluten is of an entirely different character from that of hard northern grown wheat.

In samples Nos. 1 and 4 the gluten is quite similar in composition; there is about the same ratio of gliadin to

glutenin in both, yet in sample No. 1 there is nearly twice as much gluten and other proteids as in sample No. 4. Sample No. 11, from Argentine Republic, is deficient in gliadin. In frosted wheat there is more gliadin than in similar sound wheat. In frosted wheat a small amount of glucose is formed, and sour acid bodies are readily produced in the flour.

Testing the Quality of Wheat Gluten.—Samples of wheat or flour in which there is an excessive amount of gliadin, or the gluten is otherwise poor, are readily detected in the following way: To an ounce of flour add a sufficient amount of water to form a stiff dough, after allowing an hour for the physical qualities of the gluten to develop place the dough in a small linen or fine cotton bag, work the mass gently with the fingers, while a small stream of water is allowed to flow on the bag. This is continued until the water that drains from the bag is clear, which indicates that the starch has been washed out. The qualities of the gluten can then be observed.

Good gluten is elastic, and when pulled, the threads are long and rope-like. Good gluten is not sticky, when flattened it has a good power to recoil, and it can be kneaded into a thin transparent mass.

Poor gluten is dark in color, very sticky, when pulled, the threads readily break, and are flat and tape-like. Poor gluten has but little power to recoil.

Bread made of Flour from which the Gliadin has been Extracted.—When the gliadin is partially removed from a sample of flour, it has a marked effect upon the bread-making qualities; when the gliadin is entirely removed the yeast has no power to expand the mass and form a light dough. In the illustration, figure No. 2 represents a section of a loaf of bread made of flour from which the gliadin had been extracted, while figure No. 1 represents a section of a loaf of bread made from the same amount of flour from which the gliadin had not been extracted.

When the gliadin was extracted, the dough was not sticky; it felt like putty, and broke off like putty. The yeast caused the mass to expand a little when first placed in the

oven, then the top of the loaf began to break apart, and the loaf decreased in size as if no yeast had been used. The loaf, when baked, was about as heavy as the same bulk of rubber.

When any of the wheat proteids, except gliadin or glutenin, are extracted the expanding and bread-making qualities of the flour are not affected. When the albumin is removed (and other water soluble proteids as well), the effect upon the appearance of the bread is not noticeable. Figure No. 3 is a section of a loaf of bread made from flour after extracting the albumin. When the salt soluble proteids (globulins) were extracted, the bread produced was normal in appearance. The gliadin and glutenin are the only proteids which give character to bread—that is, provided the bread is properly made.

No. 1.
Bread made from normal flour. The same amount of flour was used in all of the tests.

No. 2.
Bread made of flour from which the gliadin had been extracted.

No. 3.
Bread made of flour from which the albumin and water soluble proteids had been extracted.

TABLE NO. XXIII.—Composition of the Gluten of Wheat.

	Source.	Protein N. X. 5.7	Proteids in Gluten.	Gliadin.	Glutenin.	Per cent. of Gluten in Form of	
						Gliadin.	Glutenin.
1. Scotch Fife	Minn. Ex Station.	14.76	12.46	7.26	5.20	58.3	41.7
2. Wellman's Fife	do	12.60	10.18	6.14	4.04	60.3	39.7
3. Red Winter Wheat		10.73	8.68	5.60	3.08	64.5	35.5
4. Early Genesee Winter		7.98	6.31	3.71	2.60	58.8	41.2
5. Ladoga	Manitoba.	9.54	8.25	5.64	2.61	68.5	31.5
6. Blue Stem	Minn. Ex. Station.	14.20	11.75	7.84	3.91	66.7	33.3
7. Crimean	Russia.	11.08	9.49	5.77	3.72	60.8	39.2
8. Frosted Spring Wheat		12.88	6.39	4.25	2.14	66.5	33 5
9. Calcutta	India.	8.13	6.70	4.90	1.80	73.1	26.9
10. No. 1 Chili	Chili.	7.01	5.62	2.92	2.70	52.0	48.0
11. La Plata	Argentine Rep.	13.38	11.84	4.99	6.85	42.1	57.9
12. Nicolaeff Azima	Russian.	10.28	8.74	5.70	3.04	65.2	34.8
13. Oregon White Winter	Chicago Market.	9.23	7.65	5.42	2.23	70.8	29.2
14. No. 2 Red Winter Wheat	do	7.01	5.56	3.77	1.79	67.8	32.2
15. No. 2 Hard Winter Wheat	do	8.83	7.31	3.99	3.32	54.6	45.4

THE DIGESTIBILITY OF BREAD.

Three experiments were made to determine the digestibility of bread. In the first experiment the bread was made from the best patent grade of spring wheat flour, while in the second and third experiments, bread made from the bakers' grade of flour, and from whole wheat flour, respectively, were used. The experiments were made with a man weighing 150 pounds. The daily exercise consisted of a four mile walk. In each of the experiments the daily ration consisted of about a pound and a half of bread, a fifth of a pound of butter, and half a pound of eggs (4 eggs). The ration was the same in each experiment, except that a different kind of bread was used. The amount of bread, butter, and eggs per day in each of the experiments was as follows:

TABLE No. XXIV.—Food Consumed Per Day.

	Experiment No. 1. Bread from Patent flour.	Experiment No. 2. Bread from Bakers' flour.	Experiment No. 3. Bread from whole wheat flour.
Bread, pounds.....	1.45	1.48	1.48
Butter, "	.19	.19	.20
Eggs, "	.51	.50	.54

These rations supplied all of the needs of the body and produced sufficient energy for a four mile walk per day. In each of the experiments about 95 per cent of the total nitrogen of the food could be accounted for, indicating that none of the vital functions had been carried on at the expenses of food which had been stored up in the body. This ration may be considered as merely a maintenance ration, and would not be suited for severe labor.

NOTE.—These experiments, as well as the experiments relating to the digestibility of potatoes, the loss of food value by prolonged fermentation in bread making, and the loss of food value when potatoes, carrots and cabbage are boiled in different ways, were made in co-operation with the office of Experiment Stations of the U. S. Department of Agriculture. The details of the experiments are not given but will be published either in the annual report of this station, or in the publications of the office of Experiment Stations.

The rations contained nearly a pound and a quarter of dry matter. The dry matter was composed of about a quarter of a pound of protein, a quarter of a pound of fat, and .85 of a pound of carbohydrates, present principally in the form of wheat starch. The nutrients of the ration were distributed approximately as follows:

TABLE No. XXV.

	Dry Matter. Lbs.	Fat. Lbs.	Protein Lbs.	Carbohydrates. Lbs.
Bread, 1.47 pounds.....	.94	.04	.14	.85
Butter, .20 "	.17	.17	.....	.....
Eggs, .52 "	.13	.04	.09	.....
	1.24	.25	.28	.85

The bread supplied all of the carbohydrates (heat producing nutrients) 65 per cent of the protein (muscle and tissue repairing nutrients), and sixteen per cent of the fat. The four eggs supplied the same amount of fat as the bread, and about 35 per cent of the protein of the ration. If the bread were purchased of the baker at 5 cents per loaf, and the butter cost 20 cents per pound, and the eggs 12 cent per dozen, the ration would cost 15½ cents per day. If the bread were home-made, and the eggs were 9 cents per dozen, and the butter 16 cents per pound, the ration would cost about 10 cents per day, exclusive of the cost of the labor of preparing the materials.

The whole wheat flour which was used in this experiment was a poor type of a whole wheat flour. It was purchased as a high grade flour, but had evidently been made from winter wheat which was deficient in protein. It contained less protein than the bakers' grade of flour, and only a very little more than the white patent flour. The samples of flour from which the breads were made had the following composition:

TABLE No. XXVI.—Composition of Flour Samples.

	Dry Matter Per Cent.	Ash. Per Cent.	Fat. Per Cent.	Protein. Per Cent.	Carbohydrates. Per Cent.
Patent Flour.....	87.64	.51	1.62	12.44	73.07
Bakers' Flour.....	91.99	.75	2.22	15.50	73.52
Whole Wheat Flour.....	93.50	.98	2.01	12.81	77.60

Omitting the details of the separate experiments, it was found that there was practically no difference in the total digestibility of the bread made from the three kinds of flour. The digestibility of the bread, as found in each of the experiments was as follows:

TABLE No. XXVII.—Digestibility of Bread.

	Bread from Patent Flour. Per Cent. Digested.	Bread from Bakers' Flour. Per Cent. Digested.	Bread from Whole wheat Flour. Per Cent. Digested.
Dry Matter.....	94	93	93
Protein.....	86	84	87
Fat.....	87	87	86
Carbohydrates.....	97	97	97

In an average sample of bread, the approximate amounts of the various nutrients are represented graphically in figure No. 4. The indigestible starch, fat, and protein are represented by the dark squares in figure No. 5.

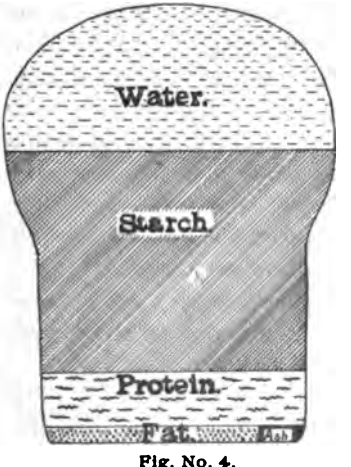


Fig. No. 4.
The Composition of Bread.

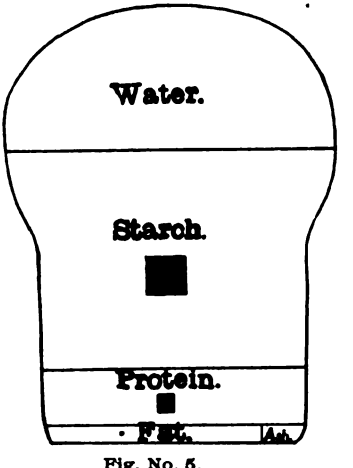


Fig. No. 5.
The Indigestible Nutrients of Bread.

COMPOSITION OF BREAD.

There is a greater difference in the composition of samples of bread, than there is in the digestibility of the bread, that is, provided the bread is properly made. Bread as ordinarily used contains about 33 per cent. of water, from 9.5 to 10 per cent. of protein, 2 to 2½ per cent. of fat, about .6 per cent. ash and salt and 54 per cent. of starch.

In comparing the food value of the different samples of bread the preference should be given to the bread containing the most protein. In some cases, however, this would be misleading, as in the bread made from the "Red Dog" grade of flour, which is rich in protein but the gluten is of poor quality and consequently the bread is of poor mechanical condition.

The whole wheat breads are not constant in composition. It is to be observed that the amount of protein ranges from 8.06 to 11.69 per cent. In many cases the whole wheat flours are made from winter wheats poor in protein, which produce a flour poorer in protein than ordinary flour. It frequently happens that whole wheat bread is purchased because it is supposed to contain more nutrients, when in reality it may contain less nutrients than ordinary bread. When the whole wheat flour is made from the best grades of wheat it will contain a little more protein than ordinary flour. It is questionable, in many cases, if this small additional amount of protein is worth the additional price usually charged for such flours. As to the superior merit of whole wheat flour over ordinary flour, it is more a question as to the quality of the wheat from which each flour has been made.

In some of the samples of baker's bread an excessive amount of lard or butter is used, which is indicated by a high per cent. of fat when the bread is analyzed.

The cost of bread is another important item. Three pounds of flour will make a little more than four pounds of bread, on account of the water which has been used in mak-

ing the bread. At two cent a pound for the flour, four loaves of bread can be made from six cents' worth of flour. With a liberal allowance of two cents for yeast and shortening, the cost of the materials in the four loaves of bread would be about eight cents or two cents a loaf, exclusive of fuel and labor. A barrel of flour costing $4.00, if purchased in the form of bread at five cents a loaf, will cost over $11.00. When flour is more than two cents per pound the cost of bread can be calculated from the figures given:

Flat Bread.—Flat bread is a type of unfermented bread which is quite extensively used in many parts of the state. It is made from either whole wheat or ordinary flour, and is baked in the form of large flat round cakes. Sometimes it is rolled very thin before baking. There is less water in flat bread than in the flour from which the bread was made. The bread is rich in protein and possesses good keeping qualities. The composition of three samples of flat bread was found to be as follows:

TABLE NO. XXVIII.—Composition of Flat Bread.

	Water Per cent.	Protein Per cent.	Fat Per cent.	Carbohydrates.	Ash Per cent.
From whole wheat flour	9.38	15.50	.70	72.92	1.50
From whole wheat "	9.03	15.63	.60	72.64	1.50
From Patent flour.....	10.54	13.44	.20	75.28	.54

The composition of other kinds of bread will be found in the tables at the close of the bulletin.

THE LOSS OF FOOD VALUE BY PROLONGED FERMENTATION IN BREAD MAKING.

In bread making the fermentation process causes a loss of dry matter. This loss by fermentation is not necessarily confined to the sugar, starch and other non-nitrogenous compounds, but the nitrogenous compounds, as the gluten, may also undergo fermentation changes. In wheat and flour nearly all of the element nitrogen is in the form of protein. It is the protein which gives flour its characteristic value as a food. As previously stated, the protein in flour is present mainly in the form of gluten. Thus it follows that any loss of nitrogen, which is the principal element of protein, means a corresponding loss of protein and of food value; hence it is unnecessary to emphasize the importance of preventing excessive losses of nitrogen by fermentation in bread making.

Inasmuch as bread is made in so many different ways, it was thought best to compare the two extreme methods in common use, viz: short fermentation and prolonged fermentation, to determine the nature and extent of the losses when each process is followed. The methods of procedure were essentially as follows: (1) Short fermentation method, making a dough of the flour, water, and yeast, kneading it thoroughly, allowing it to rise until it doubled its bulk, kneading it again thoroughly, when after rising a second time it was baked. (2) Prolonged fermentation method making a batter out of the flour, yeast, and water, allowing this batter to ferment for 10 or 15 hours, usually over night, then adding more flour, kneading and allowing the dough to rise, when it was given the same treatment as in the first method. In the first method a larger amount of yeast was used and the fermentation was carried on for a shorter time and at a higher temperature, while in the second method a

smaller quantity of yeast was used, and the fermentation was carried on for a longer time and at a lower temperature.

Seven separate bread making trials are recorded; in four of the trials the bread was made by the slow fermentation process, and in three of the trials by the rapid fermentation process. In the prolonged fermentation trials the fermentation process was continued from twenty to forty hours, a longer time than is usually the case in bread making. The time of fermentation and other details, are given in the tables at the close of the article. About 400 grams of flour (14 ozs.) were first carefully weighed, and the amount of unused flour, after mixing and kneading the dough, was weighed, and deducted from the weight of flour taken. The flour, yeast, and bread were all weighed and analyzed, and the amount of dry matter and nitrogen lost in each of the trials was determined. The bread was all made from one lot of hard spring wheat patent flour. No milk or fat was used in making the bread, thus avoiding complications from the introduction of foreign materials. The details of the separate trials were carried out by Miss A. M. Pattee.

It is not intented to convey the idea that for ordinary bread making purposes so large a quantity of yeast, as was used in some of these experiments, is necessary. An ordinary yeast cake weighs about 12 grams. While the length of time for fermentation as given for some of the trials is excessive, the losses of both dry matter and nitrogen were not in all cases found to be proportional to the time of fermentation. In some of the trials, not reported, it appeared that the greatest losses occurred during the first twelve or fifteen hours of the prolonged fermentation. Briefly stated, the losses were found to be as follows:

Loss of Dry Matter.—When the bread was made by the short fermentation process, there was a loss of 1.74 per cent of dry matter equivalent to a loss of a little more than three pounds of flour per barrel. When the bread was made by the prolonged fermentation process there was a loss of 8.08 per cent of dry matter, equivalent to a loss of about fourteen and a half pounds of flour for every barrel of flour used.

Loss of Nitrogen.—When the bread was made by the

short fermentation process there was an average loss of 2.10 per cent of the total nitrogen; with the prolonged fermentation process the loss of nitrogen was 7.77 per cent. When a barrel of flour is made into bread by the prolonged fermentation process, the loss of nitrogen exceeds the loss by the short fermentation process in protein value equal to about seven pounds of the best sirloin steak.

TABLE No. XXIX.—Summary of Losses.

	Short Fermentation.			Prolonged Fermentation.	
No.	Dry Matter. Per Cent Lost.	Total Nitrogen. Per Cent Lost.	No.	Dry Matter. Per Cent Lost.	Total Nitrogen. Per Cent Lost.
1	3.94	1.50	2	11.09	8.14
3	.13	1.76	4	5.94	10.23
5	2.25	1.95	6	9.29	6.80
			7	6 01	5.93
Average	2.10	1.74		8.08	7.77

TABLE No. XXX.—Weight in Grams of Materials used and of Bread Produced.

Short Fermentation.

No.	Flour.	Yeast.	Water.	Time (hours)	Bread.
1	353.57	6.85	230	2½	512.76
3	366.34	6.27	230	2½	520.7
5	332.28	6.57	230	2½	445.1

Prolonged Fermentation.

2	378.2	1.68	230	23	490.1
4	390.67	2.66	230	22	525.7
6	435.8	2.45	.....	40	553.6
7	415.7	2.35	.....	23	566.1

TABLE No. XXXI.—Weight in Grams of Dry Matter and Nitrogen in Materials Used and Bread Produced.

Short Fermentation.				
	Flour and Yeast.		Bread.	
No.	Dry Matter.	Nitrogen.	Dry Matter.	Nitrogen.
1	317.7	7.526	312.9	7.229
3	328.6	7.820	322.8	7.81
5	299.4	7.076	293.5	6.917
Prolonged Fermentation.				
2	339.2	7.937	310.6	7.057
4	349.	8.218	313.3	7.73
6	389.2	9.156	362.7	8.304
7	371.2	8.783	355.3	8.208

TABLE No. XXXII.—Composition of Flour and Yeast.

	Flour.	Yeast.
Water, per cent. - - - - - - - - -	10.853	65.49
Nitrogen, per cent - - - - - - - - -	2.09	2.00

Composition of Bread Samples.

	1	2	3	4	5	6	7
Water, per cent.	38.962	36.69	35.15	40.44	35.54	34.52	37.23
Nitrogen, per cent.	1.41	1.44	1.52	1.47	1.52	1.47	1.45

THE DIGESTIBILITY OF POTATOES.

The digestibility of potatoes when used as food for domestic animals has been determined by a number of investigators, but few experiments, however, appear to have been made with potatoes as a human food. Inasmuch as potatoes form such an important part of the food of many people, and there is such a difference of opinion regarding their digestibility, it was considered best to determine the digestibility by actual experiment. The experiment was performed with a man weighing about 140 pounds. The daily ration consisted of 3½ pounds of boiled potatoes, 8 eggs, 1½ pints of milk, and half of a pint of cream. It was the intention to confine the ration to eggs and potatoes, but this was found impracticable on account of the potatoes making the ration too bulky. The experiment was carried on for four days. The daily ration contained, approximately, the following amounts of nutrients:

TABLE No. XXXIII.

	Dry Matter lbs.	Ash. lbs.	Protein. lbs.	Fat. lbs.	Carbohydrates. lbs.
Potatoes, 3½ pounds..	.80	.032	.09	.001	.66
Eggs, 8.....	.25	.009	.11	.108	—
Milk, 1½ pints.....	.20	.011	.06	.06	.067
Cream, ½ pint.....	.09	.003	.01	.075	.008
Total.....	1.34	.055	.27	.244	.735

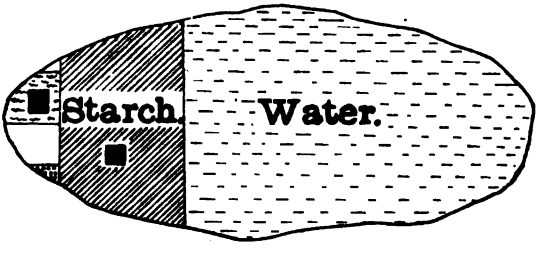
The daily ration contained 1.34 lbs. of dry matter. The dry matter was composed of about a quarter of a pound of fat, a little more than a quarter of a pound of protein, and nearly three-quarters of a pound of carbohydrates. This

ration supplied all the requirements of the body and produced enough energy for moderately hard labor.

Without entering into the details of the experiment, the digestibility of potatoes was found to be as follows:

	Per cent. Digestible.
Dry matter	89.9
Ash	62.
Protein	67.
Starch and other carbohydrates	94.

About ninety per cent. of the dry matter of the potato was found to be digestible. Of the protein, 67 per cent. was digested. The starch and other carbohydrates were found to be the most digestible of all the nutrients. No figures are



Protein. Fat. Indigestible.

Fig. No. 6. Showing the Composition of the Potato.

TABLE No. XXXIV.

	In 100 pounds of Potatoes.	
	Total Pounds.	Pounds Digestible.
Dry Matter	25.	22.5
Ash	1.0	.6
Fat	.1	—
Crude Protein	2.5	1.7
Fiber	.3	—
Carbohydrates	20.	19.

given for the digestibility of the fat, because the potato contains such a small amount of fat that its digestibility can not be accurately determined. The digestible part of the potato is composed mainly of starch, which is a valuable heat-producing nutrient. The protein of the potato is not as digestible as the protein from other foods. As far as total digestibility is concerned, this experiment indicates that potatoes occupy a high place among our vegetable foods.

The average composition of potatoes, and the amount of digestible nutrients present are as given in Table 34 on preceding page.

THE LOSS OF FOOD VALUE WHEN POTATOES ARE BOILED IN DIFFERENT WAYS.

In boiling potatoes, five or six different methods of procedure may be followed; one of the most common ways is to (1) peel the potatoes, soak them in cold water for an indefinite period, and boil them, starting with cold water. (2) Another way is to omit the soaking, and to place the potatoes directly into either hot or cold water to boil. (3) Sometimes the potatoes are not peeled, but after cleaning, are placed directly into the kettle of either hot or cold water for boiling. The cooking of potatoes so as to retain the highest amount of food value is a very important question.

Lawes and Gilbert have shown that from 80 to 85 per cent. of the nitrogen of potatoes is in the juice, and that the same proportion of the mineral matter may also be in the juice. They suggest that the boiling should be conducted so as to retain the albumin, which is soluble in water. No figures of losses from actual trials are given, but they suggest that the losses may be very large. In Bulletin No. 42, from this station, the losses of albumin were found to range from 2 to 80 per cent. of the total amount in the potato, according to the way in which the potato was boiled.

It was considered advisable to make further trials, using different kinds of water, as hard lime water, alkali water, and distilled water. Twenty-eight separate trials were made. In each trial from three to five fair-sized potatoes were used, the boiling was done in a metallic kettle over a gas flame, at about the same rate as with a good fire in a stove. Both the potatoes and water in which the potatoes were boiled were analyzed.

When the potatoes were peeled, soaked in water five hours, and started in cold water over 57 per cent. of the total nitrogen was extracted and lost. In the earlier trials, reported in Bulletin No. 42, when the potatoes were cut into medium-sized pieces, soaked and boiled slowly, 80 per cent. of the total nitrogen was extracted and lost in the drain water. The losses of nutrients are the heaviest when the potatoes are peeled, sliced, soaked and then boiled slowly, starting with cold water.

The losses of nutrients are the least when the potatoes are not peeled, and are placed directly into hot water, or even cold water, provided the water is warmed rapidly. The loss of total nitrogen is then reduced to about one per cent. When the potatoes are peeled and placed directly into hot water about eight and a half per cent. of the total nitrogen is extracted and lost. If the potatoes are peeled and placed in a kettle containing cold water the losses are much greater. The smaller the pieces and the slower the rate of cooking the greater the losses.

The losses were about the same with hard lime water, alkali water, and distilled water. The losses of starch and dextrin are insignificant compared with the losses of nitrogen and ash. When the potatoes are not peeled the combined losses of starch and dextrin are less than a tenth of one per cent. When the potatoes are peeled the loss of soluble starch and dextrin ranges from .63 to 1.50 per cent.

The loss of such a large proportion of the total nitrogen of the potato is a serious matter. Before cooking there is about one part of protein to every 10 or 11 parts of starch and starch-like bodies. After improper cooking, and losing half of the total nitrogen the ratio is widened to 1 to 20 or

more. In a bushel of potatoes a loss of 25 per cent. of the vegetable albumin is equivalent in food value to all of the protein in a pound of sirloin steak. In many cases the losses are even greater than 25 per cent.

These trials suggest, that in order to retain the highest food value: (1) Potatoes should not be peeled and soaked. (2) They should be placed directly into hot water. (3) The potatoes should not be cut into fine pieces. (4) An unnecessarily large amount of water should not be used for boiling.

TABLE NO. XXXV.—Summary Table of Average Per Cent. of Loss.

No. of Trials.		Dry Matter.	Ash	Total Nitrogen.	Starch, etc.
6	Potatoes not peeled and placed in boiling water.....	.44	3.41	1.05	——
6	Potatoes peeled and placed in kettle of cold water.....	3.43	16.18	8.52	1.01
6	Potatoes not peeled and placed in kettle of cold water..... (followed by rapid boiling.)	4.20	2.40	.98	.07
6	Potatoes peeled and placed in kettle of cold water.....	3.09	18.91	15.92	.99
2	Potatoes peeled, soaked and placed in kettle of cold water..	6.48	33.49	51.72	——
2	Potatoes peeled, sliced, soaked and placed in kettle of cold water.....	——	——	80.	——

THE LOSS OF FOOD VALUE WHEN CARROTS ARE COOKED IN DIFFERENT WAYS.

In the preparation of carrots for the table, it is usually the custom to place the sliced carrots into either hot or cold water, and boil them until they are soft and easily punctured with a fork. The water in which the carrots have been boiled is usually drained off and thrown away. This water is colored yellow and has a very sweet taste, plainly indicating that some of the nutrients of the carrots have

been extracted and are lost, and that the boiled carrots have a different composition and food value from the uncooked carrots.

In order to determine just how much food value is lost in the drain water from boiled carrots, twelve separate trials were made, in which lime water, alkali water, and soft water (distilled water) were each used. A sample of the carrots used was analyzed. The carrots were prepared by washing and cleaning with a brush, scraping, and before weighing were dried quickly with a towel to remove surplus water. The drain water, as well as the smaller amount of distilled water used for rinsing were also weighed and analyzed. From the weight and analysis of the carrots and the weight and analysis of the drain waters the amounts of nutrients extracted and lost were calculated. The carrots were sliced in wedge-shaped pieces about four or five inches long. In some of the trials the pieces were smaller, while in others they were larger. The carrots were cooked in a metallic kettle by means of a gas burner, under as nearly normal conditions as possible. The rate of boiling was very similar to that on a gasoline stove.

Composition of the Carrots.—The carrots used contained 12.50 per cent. dry matter, which is practically the amount given for the composition of American carrots. A little over half of the dry matter was cane and fruit sugar,—viz., 6.60 per cent., of which 3.66 per cent. was cane sugar and 3.00 per cent. was fruit sugar and glucose. The amount of nitrogen in the carrots was .18 per cent., equivalent to 1.12 per cent. of crude protein. About 44 per cent. of the total nitrogen was present as albuminoid nitrogen.

The Losses in the Drain Waters.—In the boiling of carrots from a fifth to over a half of the total nutrients are extracted and lost in the water used for boiling. The amount of loss depends more upon the size of the pieces and the rate of boiling than it does upon the kind of water employed. With small-sized pieces and slow boiling half of the nitrogen may be extracted and lost. The most serious losses are of the nitrogenuous compounds and the fruit sugar. There appears to be a larger loss of the nitrogenuous compounds

than of sugar. Unlike the potato, there appears to be about the same relative loss of nitrogen when the carrots are placed directly into hot water, as when placed in cold water. This is probably due to the presence of the large amount of sugar and other extractive matters which leave the carrots in such a porous condition that the coagulated albumin cannot be retained.

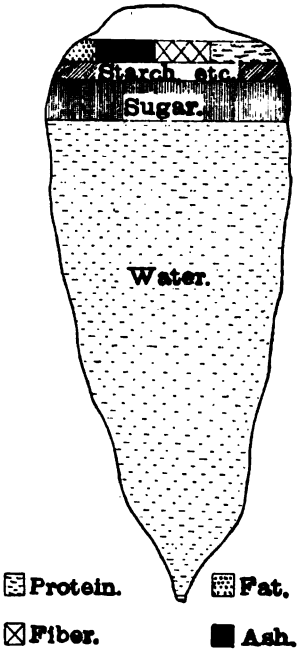


Fig. 7. Composition of a carrot.

These trials suggest that in the cooking of carrots (1) the pieces should be large rather than small, (2) that the boiling should be rapid rather than slow, (3) that as little water as possible should be used, (4) and that this extractive matter should be used as food along with the carrots instead of being thrown away, so as to prevent the loss of the 20 to 30 per cent. of the most valuable nutrients of the carrot.

TABLE No. XXXVI.—Summary. Average Per Cent of Loss.

	Dry Matter	Ash.	Total. Nitrogen.	Sugar.
Carrots cut in Small Pieces.....	29.93	47.91	42.49	25.92
Carrots cut in Medium Sized Pieces	23.57	37.45	27.64	26.00
Carrots cut in Large Pieces.....	20.18	29.70	20.22	15.40

THE LOSS OF FOOD VALUE WHEN CABBAGE IS COOKED IN DIFFERENT WAYS.

Similar experiments were made to determine the extent of the losses when cabbage was boiled by beginning with hot or cold water. In each trial one half of a fair sized solid cabbage was used. The cabbage was first weighed, and then boiled in a metallic kettle over a gas flame. The drain waters were also weighed and analyzed. The rate of boiling was the same as in the experiments with potatoes and carrots. Distilled water, lime water, and alkali water were each used in the hot and cold water trials.

Composition of the Cabbage.—The cabbage contained 92.52 per cent water, .70 per cent ash, .18 per cent nitrogen, equivalent to 1.12 per cent of crude protein. Sixty-one per cent of the total nitrogen was in the form of albuminoid nitrogen.

The Losses in the drain water from boiled cabbage are very large. Even under the most favorable conditions,—starting with hot water and boiling rapidly—the lowest amount of dry matter lost amounted to 29 per cent of the total dry matter in the cabbage, while about a third each of total nitrogen and ash were lost. The heaviest losses occurred when the cooking was started with cold water, when over 42 per cent of the total dry matter was extrated, and nearly half of the total nitrogen and over half of the ash were lost. On account of the leafy and porous structure of the cabbage a larger amount of surface is exposed to the action of the water used for boiling. In the boiling of cabbage the losses can not be held in check as effectually as in the boiling of potatoes. It is sometimes customary to soak cabbage before boiling, in which case the losses must be even larger. The loss of the dry matter, containing from a third to a half of both the total nitrogen and, ash seriously lessens the food value of the cabbage. It means that when a hundred pounds of cabbages are boiled there is only about 5.50 pounds of dry matter actually consumed, while 2.25 pounds containing the most valuable nutrients of the cabbage are lost.

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THE RATIONAL FEEDING OF MEN.

HARRY SNYDER.

Importance.—The object of the rational feeding of man is to supply the human body with the proper amounts of the right kinds of food. In the feeding of man, as in the feeding of animals, the best results are obtained in the way of economy, health, and amount of labor that can be performed, when the body is supplied with the proper nutrients for the production of heat and energy, and for the necessary repair of the worn-out tissues.

In order to discuss the subject it will be necessary to consider the composition of foods, the uses made of foods by the body, the amount of food required for different kinds of labor, the combination of foods to form balanced rations so as to meet all of the requirements of the body, and the comparative cost and value of various kinds of foods.

COMPOSITION OF FOODS.

Many of our common food materials as meat, and the various vegetables are very complex in composition, in fact the exact number and nature of the compounds in an ordinary food material are not known. Although foods are composed of many compounds, the main difference in composition between two foods is, as a rule, confined to a few of these compounds. One food differs from another in containing more or less of some nutrient as starch, sugar, fat or albumin.

In dealing with the composition of foods it is necessary to make use of a number of terms as nutrient, dry matter, organic matter and protein, which will first be briefly defined.

NOTE—This article has been condensed from lecture notes given as a part of the course in chemistry at the Minnesota School of Agriculture. The material has been compiled largely from the works of Konig, Voit, Atwater and the publications of the U. S. Department of Agriculture.

A nutrient is either a compound or a group of compounds capable of serving some purpose as food. Sugar, fat, and albumin are nutrients because they are compounds which can be used by the body as food.

Water as a Constituent of Foods.—All foods contain water. In the white of the egg, in milk, in vegetables and in the juices of meats the water is perceptible, while substances like meal, flour and sugar, which appear perfectly dry, contain water.

Dry Matter, or Solids.—Whenever the water is entirely removed from any substance, the material which is left is called the dry matter or solids. When all of the water is removed from a sample of milk it leaves a brittle shining residue called the milk solids. If a quart of milk is weighed, and all of the water removed in the way to be described, it will be found that about four and a half ounces of solid material are obtained. At the same rate a hundred pounds of milk would give about 13 pounds of solids.

How the Water in Foods is Removed.—The water in any food or other substance is removed by drying the material at the temperature of boiling water. This is accomplished by drying in a water oven, which is made of tin or copper and has double walls. The space between the walls is filled with water which is kept boiling.

When any food is dried in such an oven, the water which is present is expelled in the form of steam, leaving what is known as the dry substance or water free material.

These two terms, water and dry matter, are used frequently in speaking of foods. When it is desired to express the amount of water which a substance contains it is always expressed in pounds per hundred of that substance. In all books and tables these figures are given as percentage amounts, which means pounds of water in one hundred pounds of the substance.

In 100 lbs. of milk	there	are	from	86 to 88	pounds	of	water.
In 100 " cheese	"	"	30 to 35	"	"	"
In 100 " flour	"	"	10 to 14	"	"	"
In 100 " butter	"	"	8 to 15	"	"	"
In 100 " beef	"	"	50 to 60	"	"	"
In 100 " chicken	"	"	70 to 75	"	"	"
In 100 " waterml'n	"	"	95 to 96	"	"	"
In 100 " sugar	"	"	.1 to 1.	"	"	"
In 100 " oysters	"	"	86 to 88	"	"	"

The amount of water in other foods is given in the tables of analyses.

It is to be observed that there is a great difference in the amount of water present in food stuffs. Whenever we buy a pound of beef we buy about half a pound of water, and when we buy a barrel of flour, from 20 to 30 pounds of water are purchased. Tomatoes, cucumbers and many other vegetables frequently contain 95 to 96 parts of water in every 100 parts of the vegetable material.

Ash.—The dry matter of foods is composed of a number of separate and quite distinct compounds, some of them as starch, sugar and fat, are familiar bodies. If this dry matter of foods is burned, a small amount of ash is obtained.

In all food stuffs, as eggs, meat and vegetables, there is a certain amount of material that is left after the substance is burned which is called the ash, or mineral, or earthy matter. In all foods there is more or less ash present, just as there is in wood or coal. In the case of milk, there is about three-quarters of a pound of ash in 100 pounds of milk. In all meats there is from a pound to a pound and a half of ash per 100 pounds of the meat. In other food stuffs this mineral matter is present in various amounts as given in the tables of the composition of foods. This mineral matter is a necessary food constituent. The ash of the food is important because it furnishes material for the formation of bones and it also enters into the composition of all of the vital fluids and every part and organ of the body. The ash is composed of a number of constituents as salt, lime, iron, phosphoric acid, etc. Foods differ materially as to the composition of their ash. In potatoes the mineral matter is

largely potash, while in grains it is composed largely of phosphates.

Organic Matter.—The dry substance which has been burned is known as the organic or volatile part of the food. The ash is called the non-volatile or inorganic part. The organic matter is obtained by subtracting the ash from the dry matter.

Fats.—One of the nutrients present in all foods is fat. The amount of fat in foods is variable. In 100 pounds of milk there may be present from 3.5 to 5 pounds of fat; in flour fat is present to the extent of one pound in every 100 pounds of flour. In lean meat from a fifth to a third of the total weight is fat. The amount of fat is least in the vegetable food stuffs, and greatest in the animal food stuffs.

There is a great difference in the quality of fat from different foods. In some cases the fat is firm and hard like tallow, while in other cases it may be in the form of an oil. Fat is not a simple material. There are a great many different kinds of separate fats; and in milk there are no less than seven or more separate fats.

The fats are sometimes spoken of when the ether extract materials are meant. Fats are soluble in ether and constitute, nearly all of the ether extract of grains, and animal food products. In fresh green vegetables the ether extract contains a great many other compounds besides fat. The ordinary figures given for the fat content of green vegetables are much higher than the actual amounts of pure fat present, while the ether extract from animal food products, and from most grain products is nearly pure fat.

The amount of fat which various foods contain is given in the tables of analyses.

Fiber.—The fiber includes the cellulose and lignin bodies which constitute the frame work of vegetable substances. The amount of fiber in human food stuffs is usually small. In ordinary flour there is about one part of fiber in 1000 parts of flour. In some foods, as the potato, the amount of fiber is sometimes exaggerated. In the potato there are three or four parts of fiber per 1000 parts of potato. The fiber is not entirely indigestible.

Carbohydrates.—The starch and sugar compounds together with similar substances constitute the carbohydrate group. As ordinarily used the carbohydrates include compounds as the organic acids, or sour principles of vegetables, the jellies or pectose substances, and many other bodies which are not carbohydrates. The term nitrogen-free-extract is frequently made use of to designate this miscellaneous group. The term nitrogen-free-extract means compounds, like starch or sugar, which contain no nitrogen, (nitrogen-free), are easily soluble bodies, and are capable of being readily extracted from foods. The term nitrogen free extract is, as its name implies, a very indefinite one.

The Non-nitrogenous and the Nitrogenous Compounds—The fat, fiber, starch, sugar, and other allied compounds constitute a group to which the name non-nitrogenous compounds is given. The non-nitrogenous compounds contain no nitrogen. Compounds like albumin, casein and fibrin contain nitrogen, and are called nitrogenous compounds. *Non-nitrogenous compounds contain no nitrogen: nitrogenous compounds contain nitrogen.* The divisions into these two classes is an important one, because each class serves a different food purpose. The nitrogenous compounds are by far the most expensive and the most important nutrients found in foods. The nitrogenous compounds are divided into groups.

Protein.—The proteids are the largest and the most important group of the nitrogenous compounds. Unfortunately, the terms used to designate the nitrogenous compounds have been confused. By many the terms proteids, albuminoids, and nitrogenous compounds are used synonymously, but each term has a distinct meaning. The nitrogenous compounds constitute the general class, while proteids and albuminoids are distinct classes of nitrogenous compounds. For food purposes the nitrogenous compounds are, by common usage, collectively spoken of as the crude protein.

Nutritive Ratio.—The nutritive ratio is the ratio which exists between the protein and the non-nitrogenous compounds. A nutritive ratio of 1 to 5.5 means one part of

protein to 5.5 parts of non-nitrogenous compounds. In calculating the nutritive ratio the fats are multiplied by 2¼ because they are so much more concentrated than the carbohydrates. In calculating the nutritive ratio the fat, after multiplying by 2¼, is added to the carbohydrates, then this sum, divided by the protein, gives the nutritive ratio. A narrow ratio means a small proportion of non-nitrogenous compounds to protein. A wide ratio means a large proportion of non-nitrogenous compounds to protein.

Miscellaneous Compounds.—In addition to the compounds which have been given, there are a great many other compounds present in foods. Many fruits and vegetables contain essential oils and other similar products which impart flavor and render foods more digestible. Many foods also contain various organic acids, as tartaric acid, found in grapes, and malic acid found in small fruits. The jellies, or pectose substances are also found in many foods. In the potato pectose substances and organic acids are both present. Some foods contain compounds, as tannic, which impart a a negative food value.

In the following chart a classification of the important compounds found in foods is given. A division is first made into water and dry matter. The dry matter is then divided into two parts; ash, and the organic or volatile part. The organic part is in turn divided into two classes of compounds: non-nitrogenous and nitrogenous. Both of these classes are subdivided as indicated on the chart. While the classification may seem somewhat complicated, it must be remembered that when we are dealing with foods we are considering very complex bodies.

Composition of Foods.

- 1. Water
- 2. Dry Matter.
  - 1. Ash.
    - Potash, soda, lime, iron, magnesia, phosphoric acid, sulphuric acid, etc.
  - 2. Organic Compounds.
    - 1. Non-Nitrogenous Compounds.
      - 1. Carbohydrates.
        - Cellulose.
        - Pentosans.
        - Starch.
        - Sugar.
        - Gums.
      - 2. Pectose substances (jellies).
      - 3. Fats.
        - 1. Olein
        - 2. Stearin.
        - 3. Palmitin, etc.
      - 4. Organic Acids.
        - Tartaric.
        - Oxalic.
        - Malic.
        - Citric, etc.
      - 5. Volatile or essential oils, compounds which impart odors.
      - 6. Mixed Compounds.
    - 2. Nitrogenous Compounds.
      - 1. Proteids.
        - 1. Albumins.
        - 2. Globulins.
        - 3. Peptones, etc.
        - 4. Albuminates.
        - 5. Insoluble proteids.
      - 2. Albumnoids as gelatine.
      - 3. Amides as asparagin.
      - 4. Alkaloids,

USES MADE OF FOODS BY THE BODY.

In order to sustain life the body must be supplied with food for the production of heat and for maintaining the body. In the case of growing children an additional amount is required in excess of that required for the two purposes named. Foods should supply all of these needs of the body.

Heat Producing Foods.—Fat, starch and sugar which belong to the non-nitrogenous compounds are generally called the heat producing compounds. A pound of starch, when it is fully digested by the body, produces the same amount of heat as if the starch were burned in a stove. In fact all of our food which is digested produces heat. In order for the functions of the body to be properly performed, a certain amount of heat is required. There is a great difference in the amount of heat which different foods are capable of producing. Some foods are greater heat producers than others.

Heat Units.—The heat which is present in foods is measured by the amount of work which it is capable of doing. The amount of heat required to raise a pound of water .8 of a degree F. is called a Calorie. A pound of sugar or starch will produce 1860 Calories; that is a pound of starch when burned, if all of the heat were used for warming water, would warm 1860 pounds of water .8 of a degree F. The heat produced by foods is sometimes spoken of as the heat units. A pound of starch or sugar will yield 1860 heat units. A pound of fat will produce 4225 heat units, about 2.25 times more heat than a pound of starch.

Starch, sugar and fat not only produce heat but may also be used for the formation of fat in the body. These compounds alone can not produce muscle or sustain life because they contain no nitrogen. The muscles, blood, skin, etc. all contain nitrogen, hence the sugar, starch and fat, are incomplete foods because they supply no nitrogen. The nitrogen

of the body must be supplied in the form of protein as albumin, or casein.

Importance of Protein.—The protein compounds are frequently called the muscle forming compounds, a term first used by Liebig. As previously stated they are the most important compounds present in foods. They are the building materials out of which the greater portion of the muscles of the body are formed. They enter into the composition of the bones, tendons and ligaments, hair, skin, nails, nerve tissues, and all of the vital fluids of the body. Every muscular act of the body is carried on at the expense of some protein material. All of these demands for protein in the human body must be met by a liberal supply in the food. It is the protein which is usually the most deficient in our food materials. The protein compounds are the vital nutrients. From what has been said in regard to the protein compounds entering so largely into the composition of the body, the necessity of combining a sufficient amount of protein in our food is apparent. Protein not only performs these functions but it also produces heat. A pound of protein when digested will produce the same amount of heat as a pound of starch or sugar.

Digested Products.—When protein is digested, the nitrogen is excreted in the form of urea. The carbon of the food appears as carbon dioxide, and the hydrogen as water, both of which are expelled in respired air. In order to form carbon dioxide and water the oxygen of inhaled air is essential. In addition to forming completely digested products as carbon dioxide, water, and urea, cleavage products are also formed. The income and outgo of the carbon of the food is studied by Petten Rofer's apparatus, by means of which all of the respiratory products, as carbon dioxide and water are accurately determined.

THE AMOUNT OF FOOD REQUIRED BY THE BODY.

The amount of food which the body requires is determined by experiments. The food is so regulated that the amount of waste matter is entirely replaced by the food consumed. The amount of food which the body demands can be as accurately determined as the amount of fuel required by an engine for different kinds of work. The amount of food required by different persons varies in the same way as the fuel requirements of different stoves. Unlike the stove, the body, when it is not supplied with food, begins to draw upon itself. Making due allowance for individual differences, the average amount of food per day required by a man at moderate physical labor is as follows:

Protein ..... .25 pounds.
Fat ..... .25 "
Carbohydrates ..... 1.00 "

Total dry matter ..... 1.50 pounds.

Heat units or fuel value of food about 3300 calaries.

The food consumed should vary with the occupation, the climate, and the characteristics of the individual. The figures for the dietary standards, calculated from many experiments by different investigators, as given by Atwater, are as follows:

TABLE No. XXXVII.—Dietary Standards.

	Protein lbs.	Fat lbs.	Carbohydrates lbs.	Fuel Value.	Nutritive Ration.
Man with little physical exercise..	.20	.20	.66	2.450	5.5
Man with light muscular work....	.22	.22	.77	2.800	5.7
Man with moderate muscular w'rk	.28	.28	.99	3.520	5.8
Man with active muscular work..	.33	.33	1.10	4.060	5.6
Man with hard muscular work....	.39	.55	1.43	5.700	6.9

It is to be observed that any increase in the amount of labor performed should be met with a corresponding increase in the amount of food consumed. The food should be regulated according to the amount of work that is to be performed. There is no question that, ordinarily, too little attention is paid to the proper combination of foods so as to furnish the nutrients according to the demands of the body. It is not intended to convey the idea that every particle of food a person consumes should be weighed, and the nutrients which it contains calculated. A general knowledge of the composition of foods will enable one to know what foods can be combined with other foods to advantage.

Some foods are rich in protein, some are rich in fat, while others are rich in carbohydrates. Take for example a few foods as butter, rice, potatoes, eggs and beef. A combination of butter, rice and potatoes would be deficient in protein and would be an unbalanced ration. A combination of beef, eggs and butter would likewise form an unbalanced ration, one rich in protein and fat, and containing no carbohydrates. If the two classes of foods are blended a good balanced ration is the result.

In the combination of foods there is sometimes a tendency to use too much fat. A certain amount of fat in the food is absolutely necessary. The carbohydrates can not entirely take the place of the fats because the body demands a certain amount of concentrated heat-producing food as fat. Too much fat is not only a waste of food but is also a detriment. Four ounces of fat daily is a fair amount, in some cases four or six ounces can be used by the body to advantage, but ten or twelve ounces per day of fat, which is frequently the amount consumed, is too much.

Example of a Balanced Ration.—The combination of foods to form balanced rations is not a difficult matter. Suppose a ration is to be made from bread, butter, potatoes, sugar, eggs, milk and some meat as round steak. The composition of each food should first be noted. In the tables of composition of foods, the nutrients in 100 pounds of the food are given. By moving the decimal point two places to the left the nutrients in one pound of the food are obtained, as follows.

TABLE NO. XXXVIII.

	Protein lbs.	Fat lbs.	Carbohydrates lbs.	Heat Units Calories.
One pound bread contains.....	.095	.02	.55	1300
One pound butter contains.....	——	.85	——	3600
One pound potatoes contains...	.02	——	.20	400
One pound sugar contains.....	——	——	.98	1600
One pound eggs (with shells)....	.12	.10	——	650
One pound round steak.....	.18	.12	——	870
One pound of milk.....	.04	.04	.05	325

The object is to combine the foods so that about .25 lbs. of protein, .25 lbs. of fat and about one pound or a little less of carbohydrates are obtained. The ration should, in bulk, contain from 1.3 to 1.5 pounds of dry matter and produce about 3000 heat units. Combining the foods named so as to obtain these amounts it would require about 8 ozs. of potatoes, 8 ozs. of steak, 12 ozs. of bread, 3 ozs. sugar, 2 ozs. of butter, 1 pint of milk and 3 eggs.

TABLE No. XXXIX.—Nutrients for One Day.

Quantity.	Food.	Dry Matter. Lbs.	Protein. Lbs.	Fat. Lbs.	Carbohydrates Lbs.
8 ozs.	Round steak.	.16	.09	.06	—-
12 ozs.	Bread.....	.50	.07	.01	.41
8 ozs.	Potatoes.. ...	.12	.01	——	.10
3 ozs.	Sugar.....	.19	——	——	.19
2 ozs.	Butter.....	.11	——	.11	——
4.5 ozs.	(3) Eggs.....	.07	.04	.03	——
16 ozs.	Milk.....	.13	.04	.04	.05
	Total.....	1.28	.25	.25	.75

The protein of this ration is supplied by the steak, bread, eggs and milk. The butter and steak furnish the larger part of the fat, while the bread, potatoes and sugar supply the carbohydrates. In order to make the ration more complete fruit or vegetables should be added.

A few examples of rations, calculated for average muscu-

lar labor, are given. The figures are for the uncooked materials as ordinarily purchased or sold in the market, average allowance being made for waste and refuse parts of the food. With the exception of the sugar and a few other articles, it is to be noted that nearly all of the foods included in the rations may be produced on the farm. The rations are given merely as outlines and may be varied to suit the tastes of the individual. All of the rations should have fruits and vegetables added to make them more complete. The eye should be trained so that the weight of all foods can be approximately determined. One should become acquainted with the comparative bulk and weight of foods so that the quantities required for rations can be told without weighing every article of food.

Notes on the Rations.—It is to be observed that the main sources of protein are cheese, beans, meat, milk, and bread. Other foods, as potatoes and rice, contain some protein, but they contribute but little to the total protein of a ration. The foods which supply fat in the largest amounts are butter, pork, ham, bacon, mutton, beef, cheese, and milk; beans, rice, potatoes, and bread contain but little fat. Nearly all of the carbohydrates are supplied by potatoes, bread, beans, sugar, rice and oat meal.

The rations are not calculated for the most severe muscular labor, but for average farm work. With light work, the amounts of food should be reduced one-third. For hard labor about twice as much food is required as for light work. The same amount of work could not be accomplished equally well with all of the rations. In ration No. III there are 1000 more heat units than in ration No. VI.

Foods which are slow of digestion should be combined with foods which are easily digested. The ration of a laboring man should not consist entirely of easily digested food, because the food will leave the stomach in so short a time that hunger will result although the ration contained the requisite amounts of nutrients.

TABLE NO. XL.—Examples of Balanced Human Rations.

Food Materials.	Amount in Ounces. (For one day.)	Dry Matter in Pounds.	Nutrients.			Heat Units.
			Protein lbs.	Fat lbs.	Carbohydrates. lbs.	
No. II.						
Beans	4	.22	.06	—	.15	397
Pork	2	.11	.01	.10	—	494
Butter	2	.11	—	.11	—	450
Bread	12	.52	.07	.01	.41	979
Potatoes	8	.17	.01	—	.10	103
Sugar	2	.12	—	—	.12	200
Cheese	4	.17	.07	.09	—	500
Eggs	4	.07	.04	.03	—	202
Milk	8	.07	.02	.02	.03	161
Total	—	1.55	.28	.36	.81	3546
No. III.						
Ham	8	.30	.08	.19	—	970
Eggs (2)	—	.04	.03	.02	—	136
Potatoes	12	.15	.02	—	.14	285
Butter	8	.15	—	.16	—	675
Bread	12	.51	.07	.01	.41	979
Milk	16	.13	.04	.04	.05	323
Sugar	3	.18	—	—	.18	300
Oat Meal	2	.12	.02	.01	.09	232
Total	—	1.52	.26	.43	.87	3900
No. IV.						
Mutton Roast	8	.17	.07	.09	—	550
Sugar	2	.12	—	—	.12	200
Butter	2	.11	—	.11	—	449
Milk	16	.13	.04	.04	.05	323
Peas (green)	4	.06	.02	—	.04	100
Rice	2	.11	.01	—	.10	204
Bread	8	.35	.05	.01	.28	653
Eggs (2)	3	.04	.02	.02	—	136
Oat Meal	2	.12	.02	.01	.09	232
Potatoes	8	.12	.01	—.	.10	163
Total	—	1.33	.24	.28	.76	3010

Table XL. Continued.

Food Materials.	Amount in Ounces. (For one day.)	Dry Matter in Pounds.	Nutrients.			Heat Units.
			Protein lbs.	Fat lbs.	Carbohydrates. lbs.	
No. V.						
Bacon	4	.18	.02	.15	—	695
Beans	4	.22	.06	—	.15	397
Bread	12	.51	.07	.01	.41	979
Butter	2	.11	—	.11	—	450
Sugar	2	.12	—	—	.12	200
Potatoes	8	.12	.01	—	.10	168
Cheese	4	.17	.06	.09	—	500
Milk	8	.06	.02	.02	.03	160
Total	—	1.49	.24	.38	.81	3544
No. VI.						
Mackerel	6	.08	.06	.02	—	135
Sugar	2	.12	—	—	.12	200
Butter	2	.11	—	.10	—	449
Milk	16	.13	.04	.04	.05	323
Bread	12	.51	.07	.01	.41	979
Eggs (3)	—	.06	.03	.02	—	204
Potatoes	8	.12	.01	—	.10	168
Oat Meal	2	.12	.02	.01	.09	232
Cottage cheese	8	.05	.04	.02	—	150
Total	—	1.30	.27	.23	.77	2835
No. VII.						
Corn meal	8	.44	.04	.02	.35	824
Beans	6	.33	.09	—	.22	595
Cheese	4	.17	.07	.08	—	500
Potatoes	12	.16	.02	—	.15	240
Bread	8	.33	.05	.01	28	650
Butter	4	.21	—	.21	—	900
Total	—	1.64	.27	.32	1.00	3719

NOTES ON THE COMPOSITION OF FOODS.

Beef.—As a general average about fifty per cent. of beef and other meats is water. When the meat is very lean it contains more water than when fat. In very lean round steak sixty-six per cent. as purchased is water, while mediumly fat round steak contains about sixty per cent. water. As a rule, the parts of the animal which contain the most fat contain the least water. The amount of refuse materials, as trimmings, bones, etc., ranges from three to sixty per cent. according to the part and condition of the meat. The refuse matter in ordinary steaks should not exceed twelve per cent. The water and refuse matter of meat make up about sixty per cent. of the butchers' weight. It frequently exceeds this amount. Of the remaining forty per cent., about fifteen per cent. is protein, and twenty-two to twenty-five per cent. is fat. The amount of ash or mineral matter in meat rarely exceeds one per cent. Beef varies so in composition that average figures, unless applied to average samples, are liable to be misleading.

The composition of beef and of all meats depends upon the condition of the animal. When in a very lean condition there is a large amount of refuse matter, and the meat contains a high per cent. of water. When in prime condition, not only is the quality of the meat better, but the meat contains less water and there is less waste and refuse matter. In the tables of analyses the composition of the various cuts of meat is given. The figures make no distinction as to the physical form of the nutrients. A high nutritive value is assigned to many of the cheaper cuts of meats. Although the nutrients in the cheaper cuts are present in less palatable forms, the total nutrients, as a rule, exceed the amounts in many of the more expensive cuts.

In veal there is less fat than in the corresponding parts of beef. In a side of veal there is about six per cent. of fat,

while in an average side of beef, as purchased, there is sixteen per cent. of fat. Veal contains more water than beef. In beef there is not so large a proportional amount of protein as in veal. As a general rule the meat from old animals contains less water, more fat, and less protein than the meat from young animals.

Mutton.—The average amounts of refuse matters in beef and mutton are nearly the same. The refuse matter in a side of mutton, as purchased, amounts to about nineteen per cent., in beef, 18.3. There is more solid matter, as a rule, in mutton than in beef. The various cuts of beef, however, contain a little more protein than the corresponding cuts of mutton. Mutton contains more solid matter, somewhat less protein, and more fat than beef.

Poultry.—In chickens and turkeys the refuse and waste materials amount to about a third of the butcher's weight. The lean meat of all fowls is rich in protein. In chickens and fowls, in general, the fat accumulates in various parts of the body rather than being evenly distributed through the tissues. In the goose, however, the amount of fat usually exceeds a third of the weight of the body. The edible portion of poultry contains more protein than the edible portion of beef. Although the per cent. of refuse material is high, the amount of protein obtained from fowls compares very favorably with the amount obtained from beef.

Pork.—The per cent. of water in pork varies according to the amount of fat present. The higher the per cent. of fat the lower the per cent. of water. In lean salt pork about twenty per cent. is water; in fat salt pork about seven per cent. is water. In ham about fifteen per cent., as purchased, is refuse. In bacon there is about eight per cent. of refuse and waste. The amount of protein in pork ranges from 1.8 in salt pork to about 15 per cent. in ham; the fat ranges from 25 per cent. in shoulder to 87 per cent. in salt pork. The high heat producing value and the low muscle-forming value of side pork, compared with other meats, are indicated in the table. A side of pork, as purchased, contains about 11 per cent. of refuse, 26 per cent. of water, 55 per cent. fat, 7 per cent. protein, and .5 per cent. ash.

Fish.—About half of the butcher's weight of fish is refuse. Fish contains a very high per cent. of water. The edible portion of all fish is about three-fourths water. Notwithstanding the fact that such a large proportion of fish is refuse and water, the per cent. of protein is relatively quite high. In the edible portion of fish there is about the same amount of protein as in the edible portion of lean meat. The amount of fat is small in cod and "white fleshed fish," and in salmon it is about the same as in beef. In salted fish there is less water than in the same kind of fresh fish.

Eggs.—About three-quarters of the entire egg (shell removed) is water. The shell makes up about 10 per cent. of the weight of the egg. About 15 per cent. of the egg is protein and 10 per cent is fat. There is a marked difference between the composition of the white and the yellow parts of the egg. The yolk contains 50 per cent. water while the white contains 87 per cent. water. The yolk contains about 31 per cent. of fat and 15 per cent. of protein. There is about the same amount of water in eggs as in potatoes; the potato is a type of starchy food, while the egg is a type of proteid food.

Cheese.—Cheese is a concentrated form of food rich in both protein and fat. The food value of cheese is generally underestimated. Cheese contains about 35 per cent. of fat and 28 per cent. of protein. A pound of cheese is more than equal in food value to a pound and a half of the best sirloin steak. Cheese is sometimes spoken of as indigestible; cheese may be slow of digestion but it is not indigestible. Experiments have shown that nearly all of the protein of cheese and ninety-five per cent of the fat is digestible. Experiments given by Kœnig show that cheese has a very beneficial effect upon the digestibility of other foods. The digestibility of the protein of maize (corn) meal, for example, was found to be 58 per cent. When cheese was added to the maize meal the digestibility of the protein of the ration was 93 per cent. There is no question but what more cheese could be used to advantage in our rations. Cheese is not a luxury, but is one of the cheapest and best of our food articles.

Milk.—Milk is one of the best types of what may be

termed a well-balanced food. A hundred pounds of milk contain about thirteen pounds of solid matter. The solid matter is composed of fat, protein, in the forms of casein and albumin, milk sugar and mineral matter. The most variable nutrient in milk is fat, the other nutrients vary but little in different samples of normal milk. In dietary studies by Professor Jordan at the Maine State College the value of milk is given as follows: "The dietaries in which milk was more abundantly supplied were somewhat less costly than the others and at the same time were fully as acceptable." "These results indicate that milk should not be regarded as a luxury, but as an economical article of diet, which families of moderate income may freely purchase as a probable means of improving the character of the dietary and of cheapening the cost of their supply of animal foods."

Wheat Flour.—The variations in the composition of wheat flour are quite pronounced. As a rule flour contains about twelve per cent water; there is more water in flour than in the wheat from which the flour is made. The protein in flour ranges from 7 to 14 per cent, according to the quality of the wheat, and the method of milling employed. In flour made by the roller process there is about 12.50 per cent protein. For bread making purposes, the quality of the gluten which forms the larger portion of the protein, is very important. The composition of gluten, and its influence upon the character of the bread product, are discussed in a preceding article in this bulletin. The per cent of ash in flour ranges from .3 to .9; in the lower grades of flour the per cent of ash is the highest. The amount of starch and starch-like bodies ranges from 68 to 75 per cent. The difference in composition between spring wheat and winter wheat flour is a difference mainly in the character of the gluten; as a rule, however, there is a little more protein in spring wheat than in winter wheat flour.

Buckwheat flour is quite different in general composition from wheat flour. Buckwheat flour contains more starch and less protein than wheat flour.

Corn meal contains less protein than wheat flour, but more than buckwheat flour. Corn meal is frequently so

much cheaper than flour that a given sum of money expended in corn meal will procure more total nutrients than the same amount of money expended in flour. When used for human food, corn meal should be combined with foods rich in protein so as to form a well balanced ration. There is no material difference in composition between yellow and white corn meal. It is a difference simply in coloring matter, which is present in the yellow meal and not present in the white meal.

Oat meal is a food which is richer in protein than either corn meal or flour. In oat meal there is about 1 part of protein to every 5½ parts of non-proteid material, which is about the right proportion for a well balanced ration. Some of the breakfast food preparations on the market contain less in the way of nutrients than the prices which are charged for them warrant. Particularly is this true of the preparations made from the starchy parts of corn. The oat starch grain is quite different in structure from the starch grain of other cereals. It is a compound starch grain, made up of segments, which necessitates a different method of treatment in the way of its preparation as food.

Beans and Peas are vegetable foods which are very rich in protein. In a pound of beans there is one-fourth more protein than in a pound of beef. Peas and beans are the only vegetable foods which approach in composition the protein content of animal bodies. In the examples of rations given, it is to be observed that in some of the rations, quite a large proportion of the protein is obtained from beans. Peas and beans should be more extensively used to take the place of expensive meats. But few experiments appear to have been made to determine the digestibility of beans or peas.

Sugar is frequently looked upon as a food adjunct rather than a food. Sugar is a valuable form of food. Granulated sugar is about 99 per cent pure. The per capita consumption of sugar in the United States amounts to about three ounces per day. There are a great many different kinds of sugar, a discussion of which would not be in the province of this bulletin. Sugar is a type of what might be termed a one-sided food; it is capable of producing heat, but alone can not sustain life. Many foods as carrots, beets and corn, contain appreciable amounts of sugar.

THE COST OF FOOD.

The market price of foods is never regulated according to the amount of nutrients which the foods contain. It should be the aim of the purchaser, and the farmer as well, to both buy and sell human food products according to their actual food values. For example, round beef steak is 10 cents per pound, and eggs are 10 cents per dozen, which is the cheaper and better food? At these prices will it pay the farmer to sell the eggs and buy beef? In order to answer this question it is only necessary to calculate the amount of nutrients in 10 cents' worth of each food. The pound of beef steak or 10 cents' worth of steak contains .18 pounds of protein, .11 pounds of fat and produces 780 heat units. Ten cents' worth of eggs will produce .18 pounds of protein, .18 pounds of fat, and 1080 heat units. The same amount of protein can be procured in either the eggs or beef, at the prices stated, but in the eggs over a half more fat can be obtained, which will produce 300 more heat units than the beef, which makes the eggs the cheaper food. When eggs are the same price per dozen that beef is per pound the eggs are the cheaper food.

When comparing two foods as to cost and food value the preference should be given to the food containing the most protein. Where there is but little difference as to the amount of protein, the preference should be given to the food containing the most nutrients in the form of fat and carbohydrates. Table No. XLI gives the amount of nutrients which can be procured for 10 cents when the various animal and vegetable foods are at the prices stated. When the prices are different from those given calculations can be made to correspond with other prices.

When milk is 5 cents a quart and round steak is 12 cents a pound, how do the two foods compare in food value? In

two quarts, or 10 cents' worth of milk there are .15 pounds of protein, .17 pounds of fat, .2 pounds of carbohydrates and the food will produce 1350 heat units. In 10 cents' worth of 12-cent round steak there are .15 pounds of protein, .09 pounds of fat, and 645 heat units. There is the same amount of protein in each, but the milk contains so much more of the other nutrients that it is by far the cheaper and better food.

When sirloin steak and mutton chops are the same price per pound, 10 cents will buy a little more protein in the form of beef, but the 10 cents' worth of mutton contains more fat which produces 370 more heat units. When ham and beef are the same price per pound about twice as much protein can be procured in the form of beef, while the 10 cents' worth of ham contains about twice as much fat as the beef. The high food value of cheese is also indicated in the table. When cheese and beef are the same price per pound, cheese is by far the cheaper food. Cheese at 18 cents per pound, is as cheap a food as beef steak at 12 cents per pound. The food value of beans is particularly worthy of notice. At 5 cents per pound more protein can be obtained in the form of beans than in any other food. It sometimes happens that when a given sum of money is expended in purchasing two food articles, more nutrients and a better balanced ration can be obtained than if the money were all expended for one food article.

From the table it will appear that at ordinary prices eggs, milk, cheese, wheat flour, oat meal, corn meal, potatoes and beans are among the cheapest foods as far as actual food value is concerned.

TABLE NO. XLI.—The Cost of Food.—Nutrients Obtained for Ten Cents When Foods Are at Different Prices.

(From 1894 Year Book Dept of Agr.)

Food Materials as Purchased. Animal Foods.	Prices per Pound. Cents.	Total Pounds.	Ten Cents will Buy Nutrients. Protein Pound.	Fat Pound.	Carbohydrates. Pound.	Fuel value Calories.
Beef:						
Neck	4	2.50	0.36	0.28		1825
do	6	1.67	.24	.19		1220
Shoulder	6	1.67	.27	.18		1270
Rib	10	1.00	.13	.21		1140
Sirloin	12	.83	.14	.16		915
do	15	.67	.11	.13		735
do	18	.55	.09	.10		605
Round	10	1.00	.18	.11		780
do	12	.83	.15	.09		645
do	15	.67	.12	.07		525
Veal:						
Shoulder	8	1.25	.21	.11		845
do	10	1.00	.17	.09		675
Loin (chops)	15	.67	.11	.06		445
do	20	.50	.08	.04		335
Mutton:						
Shoulder	5	2.00	.26	.37		2050
do	7	1.43	.19	.26		1465
do	10	1.00	.13	.19		1025
Loin (chops)	8	1.25	.16	.39		1935
do	12	.83	.11	.26		1285
do	16	.63	.08	.19		975
Pork:						
Smoked ham	12	.83	.06	.31		1430
do	16	.63	.04	.24		1090
Smoked shoulder	8	1.25	.16	.41		2030
Salt pork, fat	10	1.00	.04	.69		2995
Fish:						
Fresh cod, dressed	6	1.67	.18	—		340
do	8	1.22	.13	—		255
Fresh mackerel, dr'e'd.	12	.83	.09	.03		300

Table No. XLI.—Continued.

Food Materials as Purchased.	Prices per Pound. Cents.	Total Pounds.	Ten Cents will Buy Nutrients.			Fuel value. Calories.
			Protein Pound.	Fat Pound.	Carbohydrates. Pound.	
Animal Foods.						
Salmon	25	.40	.06	.04		270
Salt mackerel	8	1.25	.18	.19		1135
do	12	.83	.12	.13		755
Salt cod, dry	6	1.67	.28	.01		525
do	8	1.25	.20	.01		395
Eggs:						
10 cents a dozen		1.50	.18	.18		1080
15 cents a dozen		1.00	.13	.12		720
20 cents a dozen		.75	.09	.09		540
Milk:						
Sweet, 4 cents a quart	2	5.00	.18	.20	.24	1625
do 5 cents a quart	2½	4.16	.15	.17	.20	1350
Butter	16	.63		.54		2275
do	20	.56		.43		1897
do	25	.45		.34		1583
Cheese.						
Whole milk	10	1.00	.28	.36	.01	1998
do	12	.83	.23	.30	.01	1665
do	15	.67	.18	.24	.01	1420
Vegetable Foods:						
Wheat flour	2	5.00	.55	.06	3.74	8225
do	2½	4.00	.44	.04	2.99	6580
Corn meal	2	5.00	.46	.18	3.56	8250
Oat meal	3	3.33	.50	.24	2.27	6160
Rice	5	2.00	.15	.01	1.59	3260
Wheat bread	5	2.00	.22	.02	1.11	2530
Milk crackers	6	1.67	.16	.22	1.16	3355
Sugar, granulated	5	2.00			2.00	3720
Potatoes, 25 cts. a bu.		2.40	.42	.03	3.66	7680
Beans	3	3.33	.74	.06	1.98	5345

TABLE NO. XLII.—Composition of Human Foods.

(From Bulletins Nos. 28 and 34, Office of Experiment Stations.)

Kind and Cut of Meat. Animal Foods.	Refuse Per Ct.	Water Per Ct.	Nutrients. Water free sub-stance Per Ct.	Protein Per Ct.	Fat Per Ct.	Ash Per Ct.	Heat Units Calo-ries.
BEEF—Chuck ribs:							
Edible portion		57.8	42.7	17.4	24.4	.9	1355
As purchased	13.8	49.3	36.9	15.0	21.1	.8	1170
Loin:							
Edible portion		60.5	39.5	18.3	20.2	1.0	1190
As purchased	13.0	52.6	34.4	15.9	17.6	.9	1040
Neck:							
Edible portion		63.4	36.6	19.2	16.5	.9	1055
As purchased	27.6	45.9	26.5	13.9	11.9	.7	760
Ribs:							
Edible portion		55.4	44.6	16.9	26.8	.9	1445
As purchased	20.8	43.8	35.4	13.4	21.3	.7	1150
Round:							
Edible portion		65.5	34.2	19.7	13.5	1.0	935
As purchased	7.7	60.7	31.6	18.1	12.6	.9	870
Rump:							
Edible portion		56.7	43.3	16.8	25.6	.9	1395
As purchased	21.4	44.5	34.1	13.2	20.2	.7	1095
Shank, fore:							
Edible portion		67.9	32.1	19.6	11.6	.9	855
As purchased	36.9	42.9	20.2	12.3	7.3	.6	535
Shank, hind:							
Edible portion		67.8	32.2	19.8	11.5	.9	855
As purchased	53.9	31.3	14.8	9.1	5.3	.4	395
Fore quarter:							
Edible portion		61.4	38.6	17.5	20.2	.9	1180
As purchased	19.4	49.5	31.1	14.1	16.3	.7	950
Hind quarter:							
Edible portion		61.0	39.0	18.0	20.1	.9	1185
As purchased	15.8	51.3	32.9	15.2	17.0	.7	1000
Cooked, corn'd & cann'd							
As purchased		53.1	46.9	28.5	14.0	4.4	1120

Table No. XLII.—Continued.

Kind and Cut of Meat. Animal Foods.	Refuse Per Ct	Water Per Ct.	Nutrients.				Fuel value Per Lb. Calories.
			Water free substance Per Ct.	Protein Per Ct.	Fat Per Ct.	Ash Per Ct.	
BEEF—Continued. Dried and smoked:							
As purchased		50.8	49.2	31.8	6.8		845
VEAL—Leg, whole:							
Edible portion		70.4	29.6	20.1	8.4	1.1	730
As purchased	15.6	59 4	25.0	16.9	7.2	.9	620
Rump:							
Edible portion		62.6	37.4	20.1	16.2	1.1	1055
As purchased	30.2	43 7	26.1	14.	11.3	.8	735
Fore quarter:							
Edible portion		71.7	28.3	19.4	8.0	.9	700
As purchased	24.5	54.2	21.3	14.6	6.0	.7	525
Hind quarter:							
Edible portion		70.9	29.1	19.8	8.3	1.0	720
As purchased	20.7	56.2	23.1	15.7	6.6	.8	570
LAMB—Leg, hind.							
Edible portion		63.9	36.1	18.5	16.5	1.1	1040
As purchased	17.4	52.9	29.7	15.2	13.6	.9	855
Loin:							
Edible portion		53.1	46.9	17.6	28.3	1.0	1520
As purchased	14.8	45.3	39.9	15.0	24.1	.8	1295
Neck:							
Edible portion		56.7	43.3	17.5	24.8	1.0	1375
As purchased	17.7	46.7	35.6	14.4	20.4	.8	1130
Shoulder:							
Edible portion		51.8	48.2	17.5	29.7	1.0	1580
As purchased	20.3	41.3	38.4	14.	23.6	.8	1255
MUTTON—Leg, hind:							
Edible portion		62.8	37.2	18.2	18.0	1.0	1100
As purchased	18.0	51.4	30.6	14.9	14.9	.8	905
Loin:							
Edible portion		50.1	49.9	15.9	33.2	.8	1695
As purchased	15.3	42.2	42.5	13.2	28.6	.7	1450

Table No. XLII.—Continued.

Kind and Cut of Meat. Animal Foods.	Refuse Per Ct.	Water Per Ct.	Nutrients. Water free substance Per Ct.	Protein Per Ct.	Fat Per Ct.	Ash Per Ct.	Fuel value Per Lb. Calories.
MUTTON—Continued.							
Neck:							
Edible portion		58.2	41.8	16.3	24.5	1.0	1335
As purchased	28.4	41.6	30.	11.7	17.6	.7	960
Shoulder:							
Edible portion		61.9	38.1	17.3	19.9	.9	1160
As purchased	21.7	48.5	29.8	13.5	15.6	.7	910
Fore quarter:							
Edible portion		51.7	48.3	15.	32.4	.9	1645
As purchased	21.1	40.6	38.3	11.9	25.7	.7	1305
Hind quarter:							
Edible portion		54.8	45.2	16.2	28.2	.8	1490
As purchased	16.7	45.6	37.7	13.5	23.5	.7	1245
Side, without tallow:							
Edible portion		53.1	46.9	15.4	30.7	.7	1580
As purchased	19.2	42.9	37.9	12.5	24.7	.7	1275
PORK—Flank:							
Edible portion		59.	41.	17.8	22.2	1.	1265
As purchased	71.2	17.	11.8	5.1	6.4	.3	365
Ham, smoked:							
Edible portion		40.7	59.3	15.5	39.1	4.7	1940
As purchased	14.4	34.9	50.7	13.3	33.4	4.	1655
Shoulder, fresh:							
Edible portion		57.5	42.5	15.6	26.1	.8	1390
As purchased	46.6	30.4	23.	8.3	14.3	.4	760
Salt, clear fat:							
As purchased		7.3	92.7	1.8	87.2	3.7	3715
Salt, lean ends:							
Edible portion		19.9	80.1	7.3	67.1	5.7	2965
As purchased	11.2	17.6	71.2	6.5	59.6	5.1	2635
Bacon, smoked:							
Edible portion		18.2	81.8	10.0	67.2	4.6	3020
As purchased	8.	16.8	75.2	9.2	61.8	4.2	2780

Table No. XLII.—Continued.

Kind and cut of Meat. Animal Foods.	Refuse Per Ct.	Water Per Ct.	Nutrients- Water free substace. Per Ct.	Protein Per Ct.	Fat Per Ct.	Ash Per Ct.	Fuel value Per Lb. Calories.
PORK—Continued. Side:							
Edible portion		29.4	70.6	8.5	61.7	.4	2760
As purchased	11.2	26.1	62.7	7.5	54.8	.4	2455
POULTRY—Chicken:							
Edible portion		74.2	25.8	22.8	1.8	1.2	500
As purchased	34.8	48.5	16.7	14.8	1.1	.8	325
Turkey:							
Edible portion		55.5	44.5	20.6	22.9	1.0	1350
As purchased	22.7	42.4	34.9	15.7	18.4	.8	1070
FISH, fresh—Cod, dried:							
Edible portion		82.6	17.4	15.8	.4	1.2	310
As purchased	29.9	58.5	11.6	10.6	.2	.8	205
Mackerel, entrails rem'd:							
Edible portion		73.4	26.6	18.2	7.1	1.3	640
As purchased	40.7	43.7	15.6	11.4	3.5	.7	360
Salmon, Cal., sections:							
Edible portion		63.6	36.4	17.5	17.9	1.0	1080
As purchased	10.3	57.9	31.8	16.1	14.8	.9	925
Salmon Trout, whole:							
Edible portion		69.1	30.9	18.2	11.4	1.3	820
As purchased	56.3	30.	13.7	7.7	5.4	.6	985
Trout, brook, whole:							
Edible portion		77.8	22.2	18.9	2.1	1.2	440
As purchased	48.1	40.4	11.5	9.8	1.1	.6	230
FISH, preserved. Cod, salt:							
Edible portion		53.6	46.4	21.4	.4	24.6	410
As purchased	24.9	40.3	34.8	16.	.4	18.4	315
Mackerel, salt:							
Edible portion		42.2	57.8	22.	22.6	13.2	1360
As purchased	22.9	32.5	44.6	17.	17.4	10.2	1050
Salmon, canned, as purchased		64.5	35.5	20.1	11.6	2.4	890

Table No. XLII.—Continued.

Kind and Cut of Meats. Animal Foods.	Refuse Per Ct.	Water Per Ct.	Nutrients. Water free substance. Per Ct.	Protein Per Ct.	Fat Per Ct.	Ash Per Ct.	Fuel value Per Lb. Calories.
FISH, preserved—Con.							*
Sardines, canned, as purchased		56.4	43.6	25.3	12.7	5.6	1010
Shell Fish.							
Clams, round:							
Edible portion		86.2	13.8	6.5	.4	2.7	215
As purchased	67.5	28.	4.5	2.1	.1	.9	65
Oysters, "solids," as purchased		88.3	11.7	6.1	1.4	.9	285
DAIRY PRODUCTS:							
Cheese—Cheddar		33.00	67.00	28.00	35.00	4.00	1999
Butter		13.00	87.00	.50	85.00	1.5	3600
*Milk		87.00	13.00	3.5	4.00	.7	323
*Cream				2.5	20.0	.5	
EGGS:							
In shell	13.7	63.1	23.2	12.1	10.2	.9	655
Edible portion		73.8	26.2	14.9	10.5	.8	721

*Milk also contains 4.8 per cent. carbohydrates. The fat content of cream ranges from 10 to 30 per cent.

Table No. XLII.—Continued.

Vegetable Foods.	Refuse Per Ct.	Water Per Ct.	Protein Per Ce.	Fat Per Ct.	Carbo-hy-drates. Per Ct.	Ash Per Ct.	Fuel value Per Lb. Calo-ries.
Wheat flours, meals, etc.							
*Roller process flour		11.9	12.6	.8	74.3	.4	1650
Spring wheat flour		11.6	11.8	1.1	75.0	.5	1660
Winter wheat flour		12.5	10.4	1.0	75.6	.5	1640
Buckwheat flour		14.3	6.1	1.0	77.2	1.4	1590
Corn meal, bolted		12.9	8.9	2.2	75.1	.9	1655
Oat meal		7.2	15.6	7.3	68.0	1.9	1860
Rice		12.4	7.8	.4	79.0	.4	1630
Rice, boiled		52.7	3.0	.1	41.9	.3	875
*White bread		31.0	9.9	1.4	57.1	.6	1306
*Graham bread		32.2	9.5	2.5	54.7	1.1	
Crackers		8.2	10.7	9.9	68.8	2.4	1895
Sugar, granulated					98.0		1600
Sugar, maple					82.8		1540
Vegetables—Asparagus:							
As purchased		94.0	1.8	.2	3 3	.7	105
Beans, dried.							
As purchased		13.2	22.3	1.8	59.1	3.6	1590
Beets:							
Edible portion		87.6	1.6	.1	9.6	1.1	210
As purchased	20.0	70.0	1.3	.1	7.7	.9	170
Cabbage:							
Edible portion		90.3	2.1	.4	5.8	1.4	165
As purchased	15.0	76.8	1.8	.3	4.9	1.2	140
Carrots:							
Edible portion		88.2	1.1	.4	9.2	1.1	210
As purchased	20.0	70.5	.9	.3	7.4	.9	170
Parsnips:							
Edible portion		79.9	1.7	.6	16.1	1.7	355
As purchased	20.0	63.9	1.3	.5	12.9	1.4	285
Peas, dried:							
As purchased		10.8	24.1	1.1	61.5	2.5	1640

*From Minnesota Analyses.

Table No. XLII.—Concluded.

Vegetables.	Refuse Per Ct.	Water Per Ct.	Protein Per Ct.	Fat Per Ct.	Carbo-by-drates. Per Ct.	Ash Per Ct.	Fuel. value Per Lb. Calo-ries.
Peas, green:							
Edible portion		78.1	4.4	.5	16.1	.9	400
As purchased	50.0	39.0	2.2	.3	8.0	.5	200
Potatoes, raw.							
Edible portion		78.9	2.1	.1	18.0	.9	380
As purchased	15.0	67.1	1.8	.1	15.3	.7	325
Potatoes, sweet:							
Edible portion		69.3	1.8	.7	27.1	1.1	565
As purchased	15.0	58.9	1.5	.6	23.1	.9	480
Squash:							
Edible portion		86.5	1.6	.6	10.4	.9	245
As purchased	50.0	43.3	.8	.3	5.2	.4	125
Turnips:							
Edible portion		88.9	1.4	.2	8.7	.8	195
As purchased	30.0	62.2	1.0	.1	6.1	.6	135
Tomatoes:							
Edible portion		96.0	.8	.4	2.5	.3	80
Green corn		81.8	2.8	1.1	14.1	.7	360
Cucumber		96.0	.8	.2	2.5	.5	70
Spinach		92.4	2.1	.5	3.1	1.9	120
Sauerkraut		86.3	1.5	.8	4.4	7.0	145

Locusts, grasshoppers, cockroaches, crickets and similar insects are all injurious to agriculture and allied pursuits, and frequently destroy not alone the crops of a farm, but those of entire counties and even states. As a knowledge of the structure, habits, etc., greatly assists us in combatting this enemy, it is very important that everyone interested in the various branches of agriculture should be thoroughly familiar with these small foes, and for this reason the following pages were prepared. They contain the description of the habits of the most destructive species of locusts, and also give the proper methods to combat them. A short description of the structure of one species is given, as well as illustrated descriptions of nearly all orthopterous insects known to exist in Minnesota.

The descriptions of many of the insects given are taken from a number of sources, but mainly from the excellent works of Scudder, Comstock, Fernald, Beutenmueller, Morse, Blatchley, and McNeill; needed material, books, etc., were kindly loaned by Professors Forbes, Garman, Osborn and others. The illustrations were made by the assistant of the writer, Mr. E. B. Forbes, who deserves especial thanks for his faithful work, by Miss Lydia M. Hart, and by W. T. Shaw, a student of the Agricultural College, who made the drawings of the anatomical details. A few others were kindly loaned by Dr. L. O. Howard, chief of the Entomological Division of the Department of Agriculture. The illustrations in the first part of the bulletin were bought from the late Prof. C. V. Riley.

The Art Engraving Co., of St. Paul, prepared the illustrations for the printer, and deserves credit for its good work.

It is the pleasant duty of the entomologist to express his sincere thanks to all persons who have aided him in the preparation of this bulletin.

OTTO LUGGER.

A Swarm of Locusts.

Onward they come, a dark, continuous cloud
Of congregated myriads numberless,
The rushing of whose wings was as the sound
Of a broad river, headlong in its course
Plunged from a mountain summit, or the roar
Of a wild ocean in the autumn storm,
Shattering its billows on a shore of rocks.

—SOUTHEY.

THE ORTHOPTERA OF MINNESOTA.

It is well known to all farmers, gardeners, fruit-growers and others that locusts, or grasshoppers, and all their allies, are the worst enemies they have to fear and to combat, especially if they belong to the migratory species and occur, as is usually the case, in vast numbers. Our state is so situated that armies of these devouring insects can be expected from time to time, and it is well to be always prepared. Since we possess a large number of native species of locusts, grasshoppers, cockroaches, etc., besides the migratory locusts, it is well that not alone the agriculturist, but all engaged in producing food and dealing in such should be able to distinguish between them, and for this purpose all the species known to occur in Minnesota have been described, and, if necessary, illustrated. All locusts, in fact all orthopterous insects found in our state, are more or less injurious, because all live mainly from plants, some of which we grow for our own use; but some species are more destructive than others, as they prefer cultivated crops, and the farmers should be able to recognize such insects at a glance.

In the First Annual Report of the U. S. Entomological Commission we can find an excellent description of the destructive power of locusts, and many of our farmers know to their cost how correct this description is. No one who has not witnessed the ravaging power of locusts can fully conceive of or appreciate it. The organization and habit of the typical locust admirably fit it for ravenous work. Muscular, gregarious, with powerful jaws, and ample digestive and reproductive systems; strong of wing and assisted in flight by numerous air sacs that buoy—all these traits conspire to make it the terrible engine of destruction which history shows it to have been under conditions favorable to its excessive multiplication. Insignificant individually but mighty collectively, locusts fall upon a country like a plague or a blight. The farmer plows and plants. He cultivates

in hope, watching his growing grain, in graceful, wave-like motion wafted to and fro by the warm summer winds. The green begins to golden; the harvest is at hand. Joy lightens his labor as the fruit of past toil is about to be realized. The day breaks with a smiling sun that sends his ripening rays through laden orchards and promising fields. Kine and stock of every sort are sleek with plenty, and all the earth seems glad. The day grows. Suddenly the sun's face is darkened, and clouds obscure the sky. The joy of the morn gives way to ominous fear. The day closes, and ravenous locust-swarms have fallen upon the land. The morrow comes, and oh! what a change it brings! The fertile land of promise and plenty has become a desolate waste, and old Sol, even at his brightest, shines sadly through an atmosphere alive with myriads of glittering insects. Falling upon a cornfield, the insects convert in a few hours the green and promising acres into a desolate stretch of bare, spindling stalks and stubs. Covering each hill by hundreds; scrambling from row to row like a lot of young famished pigs let out to their trough; insignificant individually, but mighty collectively, they sweep clean a field quicker than would a whole herd of hungry steers. Imagine hundreds of square miles covered with such a ravenous horde, and one can get some realization of the picture presented in many parts of the country west of the Mississippi during years of locust invasion. Their flight may be likened to an immense snow-storm, extending from the ground to a height at which our visual organs perceive them only as minute, darting scintillations, leaving the imagination to picture them indefinite distances beyond. It is a vast cloud of animated specks, glittering against the sun. On the horizon they often appear as a dust tornado, riding upon the wind like an ominous hail storm, eddying and whirling about like the wild, dead leaves in an autumn storm, and finally sweeping up to and past you with a power that is irresistible. They move mainly with the wind, and when there is no wind they whirl about

in the air like swarming bees. If a passing swarm suddenly meets with a change in the atmosphere, such as the approach of a thunder storm or a gale of wind, they come down precipitately, seeming to fold their wings, and fall by the force of gravity. At other times, in alighting, they circle in myriads about you, beating against everything animate or inanimate; driving into open doors and windows; heaping about your feet and around your buildings; their jaws constantly at work biting and testing all things in seeking what they can devour. In the midst of the incessant buzz and noise which such a flight produces, in the face of the unavoidable destruction everywhere going on, one is bewildered and awed at the collective power of the ravaging host, which calls to mind so forcibly the plagues of Egypt. The noise their myriad jaws make when engaged in their work of destruction can be realized by any one who has fought a prairie fire, or heard the flames passing along before a brisk wind, the low crackling and rasping — the general effect of the two sounds is very much the same. Nothing, however, can surpass the prophet Joel's account of the appearance and ravages of these insects.

While the destruction of crops by the winged insects is often sudden and complete, the unfledged insects still more effectually, though more slowly, denude a country of vegetation, sometimes rendering the ground as bare and desolate in midsummer as it is in the Mississippi Valley in midwinter. The little creatures are often so thick, soon after hatching, that they blacken everything, and their hopping, as one passes through a field or piece of prairie, gives the impression, at a short distance, of heat flickering in the air.

Minnesota has been frequently visited by locusts in years previous to those in which such occurrences were historically recorded, and the traditions of the Indians mention that these insects had formerly taken possession of the country, holding it for seventeen years, and that in times past they had consumed all vegetation as far east as Stillwater. The

statement made by Capt. Jonathan Carver (in his "Narrative" of the year 1766), that large swarms of locusts "infest these parts and the interior colonies and oftentimes do much mischief," shows that such occurrences took place and were repeated. Of course it is rather difficult to say what the Captain meant by "these parts," but the usual application of the word "interior" is to the regions west of the Great Lakes.

The visitation of Lord Selkirk's Red River colony in 1818 by locusts extended to portions of Minnesota. In 1830 and 1842 parts of the state were overrun by locusts; in 1849 they were found in vast numbers along the prairie regions west of the big woods; in 1857 locusts destroyed all the crops in the Red River Valley, so that the infant colony did not have any grain, but was obliged to live by hunting and fishing. The papers published in Minnesota during the summer and autumn of 1856 are full of accounts of invading swarms of locusts, and they reached the region lying along the Upper Mississippi. They occurred in vast numbers at the Chippewa Agency at Gull Lake (Cass county), and arrived at Otter Tail Lake on July 24. During the last days of August they reached St. Anthony. Judging from the accounts published they swept over the whole region west of the big woods. The records of the hatching swarms of 1857 are still more numerous; the insects caused immense damage, "appearing in such masses as to crackle beneath the feet of persons walking over the prairies." When they left they went south and southeast, "for several days they were high in the air, like a snow storm." From 1863 to 1877 there was hardly a year in which the locusts did not make themselves noticeable within our borders, but principally in the Red River Valley when not heard of elsewhere. The "oldest inhabitant" of Moorhead, Mr. Robert Probstfield, gave the following years in which locusts appeared in that vicinity: "In 1863, 1864, 1865 (in 1865 very little damage done; not numerous), 1866, 1867, 1869 (in a few localities

bad, in others less, in a few none), in 1870, 1871, bad, 1872, bad, 1873, 1874, 1875, 1876." In 1877 the young locusts hatched in forty-two or more counties, lying mainly in the southwestern quarter of the state, the area, however, not reaching the southwestern corner. In the central part of the egg-area they hatched in excessive numbers. A portion of the eggs were destroyed by parasites, or at least failed to hatch. During the months of May and June an unusual amount of rainfall delayed or even prevented hatching, while owing to the large number of cool, cloudy, or rainy days, on which the locusts were averse to eating, the wheat attained a very luxuriant growth, becoming every day less capable of being injured. Still the injury was considerable, but the farmers and citizens were battling manfully with their little foes. For a time the prospect in Minnesota was gloomy, but the favorable weather together with the substantial aid and encouragement of the governor, Hon. John S. Pillsbury, and the business men of the cities and towns and railroad companies, induced the farmers to fight the battle through. In spite of all this the locusts were so numerous in some counties as to destroy the larger part of the wheat crop, and some nineteen counties* in all lost more or less; still the state raised a fine crop of wheat.

The locusts that hatched in Minnesota commenced to rise late in June, but most of them flew from July 1 to July 7 towards the northwest. Later, and until early in August,

* *Counties.*	*Acres.*	*Counties.*	*Acres.*
Kandiyoki	35,337	Todd	6,868
Chippewa	15,638	Renville	19,924
Wright	18,747	Sibley	8,799
Stearns	43,294	McLeod	20,315
Nicollet	6,151	Meeker	32,786
Pope	18,218	Yellow Medicine	12,700
Douglas	18,788	Brown	14,215
Swift	13,318	Redwood	6,803
Otter Tail	30,711		
Stevens	8,106	Total, 19 Counties	337,188
Grant	6,470		

the wind was quite changeable, and the insects seemed to beat about, sometimes going northwest, and at other times retracing their course, flying southeast and south. Towards the middle of August the winds became more constant from the northwest, and the direction of flight more constant south and southeast, until all the healthy locusts had left.

Since that time portions of the state were twice invaded by this species of locust, viz., the Migratory Locust (*Melanoplus spretus*). The history of both invasions has been given in former bulletins, and only the essential points will be repeated. It seems that during the summer of 1885 a few struggling specimens of this migratory locust reached Otter Tail County (Perham). Their offspring were seen again in 1886, when they caused but very slight damage; in 1887 they had already increased to such an extent that the crops of 3,000 acres were swept away. In 1888 people became alarmed and appealed to the governor, A. R. McGill, for assistance. Many machines, hopper-dozers, were used to kill the enemy, and with good results. Nearly 200 of such machines were at work, each having a superficial surface of over 4,800 square inches. The men operating them were requested to keep a measurement in inches of locusts swept off the pans; they reported from two to twenty-one inches daily, which would make about 5,000 bushels of dead locusts, and as these were quite small at the time, not much larger than a grain of oats, it takes an immense number to fill a bushel measure. At Perham another method was adopted by the citizens, who offered a bounty of one dollar per bushel. The quantity of locusts caught by the "balloon hopper-catcher," the invention of Mr. A. Maguire, was astonishing, and 14,643 bushels were caught and paid for between the first and the twenty-seventh of July. As it required about 7,000 locusts to fill a bushel measure, 102,438,000 were destroyed by this means alone. All told about 35,000 bushels of locusts were killed in Otter Tail county before they had caused very great loss.

In 1889 about the same area was infested, but as money had been appropriated by the legislature to combat the insects before they were hatched, no loss was caused by them. Instead of depending alone upon "hopper-dozers" and "balloon-catchers," the fields that were found to be filled with eggs were deeply plowed. Other remedies were also applied, as will be mentioned in the proper place. In all 6,361.59 acres were plowed, and with most excellent results.

In 1891 another invasion, on a smaller scale, took place. This time parts of the Red River Valley were invaded, not alone by the Rocky Mountain Locust, but also by two other species of migratory kinds, the Lesser Migratory Locust (*Melanoplus atlanis*), and the Pellucid Locust (*Camnula pellucida*). By the immediate use of hopper-dozers and other means farmers succeeded in preventing serious loss, and being forewarned they plowed every field that was even suspected of containing eggs, and on this account no locusts appeared in 1892.

Since that time (1891) the state has been free of this dreaded insect, but, as may be judged from the history of invasions just given, our farmers can not expect that these migratory locusts will not again appear in the future. In fact, our state, or rather portions of our state, are uncomfortably near the permanent breeding grounds of this locust, which extend chiefly along the eastern Rocky Mountain range, from longitude 102° to 140° west of Greenwich, and from latitude 53° to 40° north, comprising most of the levels below an altitude of 6,000 feet and above 3,000 feet. In many portions of this area they breed every year, and lead an essentially migratory existence. This permanent breeding area gradually shades into a sub-permanent region, in which locusts breed more or less frequently, and which is liable to be invaded at any time, or rather whenever the insects become very numerous in their true breeding grounds. This region includes a large portion of British America, nearly all of the Dakotas, Western Nebraska,

Northwest Kansas, and the northern half of Colorado. Although Minnesota may be said to be located in the temporary region, i. e., a region only periodically visited, yet parts of our state are unpleasantly near the boundary or danger line, and therefore apt to be overrun by hordes of hungry locusts, and such has been frequently the case as shown above. From 1863 to 1878 there was hardly a year in which locusts did not occur in sufficient numbers to injure the crops somewhere. When not occurring elsewhere they were surely found in the Red River Valley. They did not breed there during all these years, but sufficient new swarms came from the Northwest to recruit the invading army and make it formidable.

As has been mentioned before, the state has been free of the Rocky Mountain Locust since 1891. At present the nearest point known to be infested with this insect is South Dakota, and farmers living near the boundary line should be on the lookout.

Besides this species, frequently also called the "Hateful Locust," two other kinds, both more or less migratory, have caused much injury. One kind, the Lesser Migratory Locust (*Melanoplus atlanis*) is still with us; at present it is chiefly confined to the country along the St. Paul & Duluth Railroad. It is a little smaller than *spretus*, though very closely resembling it. Its wings are also much longer than the body, which enables it to fly long distances. This species is essentially an Eastern one, being found in larger or smaller numbers from the northern part of Florida to the extreme north of Eastern United States. Like the hateful Western locust it is single-brooded in Minnesota; it matures more rapidly, becoming winged quite early in July. Eggs are deposited soon afterwards, and oviposition continues until cold weather. This insect is sometimes called the "White Mountain Locust," from the fact that the great losses to all sorts of crops sustained in different regions of New England from locusts are almost all caused by this

insect. As a full account of it has been given in the First Entomological Report of Minnesota (Bulletin No. 43) it is not necessary to repeat it here. The illustration (Fig. 1, *d*, *e*, *f*), shows this species.

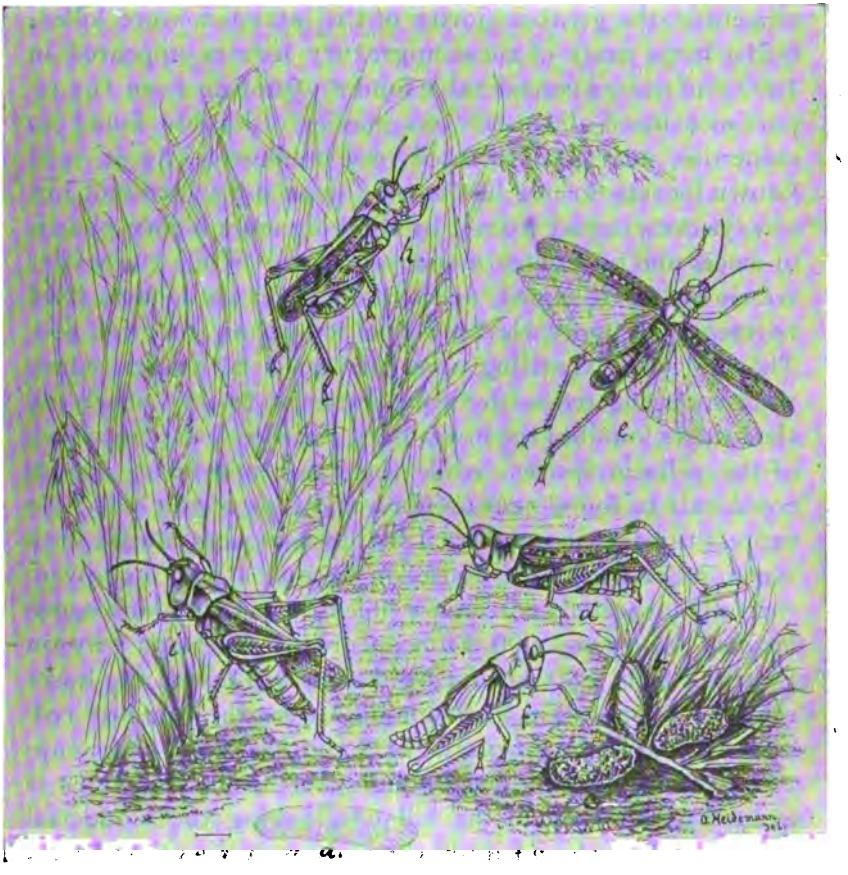


FIG. 1.—*a*, single egg of Pellucid Locust; *b*, egg-mass opened to show eggs inside; *c*, egg-mass; *i*, female; *h*, male. Lesser Migratory Locust; *d*, female; *e*, male; *f*, pupa. Natural size. Original.

The other kind of migratory locust (*Camnula pellucida*) (Fig. 1, *i*, *h*) is no longer found in Minnesota. It was, however, with us since the autumn of 1891, and caused con-

siderable damage together with *atlanis*. Especially the vicinity of Duluth was invaded as early as the summer of 1891. The insects became very numerous and caused considerable damage to lawns and gardens in 1892, but as a parasite, the Tachina-fly described later, became still more numerous the great majority of the intruders were killed. Still a large army of these migratory locusts appeared in 1893 and caused considerable injury. Quoting from the report mentioned above the two species of locusts found so numerous near Duluth acted very peculiarly. As is well known locusts do not like to rest upon moist ground, but always crawl away from it by climbing upon higher plants, or fences and outhouses if such are near. While the writer was in Duluth it rained, and consequently the locusts tried to escape to more elevated positions than the wet soil. They did so by crawling upon the walls of houses, which were soon covered with them. Strange to say nearly all the locusts found in the lower part of the city were members of the pellucid species, while the lesser migratory species could only be found near or upon the tops of the hills. To express this fact in numbers, 1,000 locusts were caught with a net on the front of a house on Second street, and were carefully inspected; all were pellucid locusts (*Camnula pellucida*). Another 1,000 were captured in the same way on Fourth street: 880 were pellucid locusts, 92 were the lesser migratory locusts (*atlantis*), and 24 were the common red-legged kind (*femur-rubrum*). Still another 1,000 were captured at the base of a large building, the Pavilion, which is located on the top of the hill overlooking the wonderful scenery of Duluth and its harbor. Here it was found that 972 specimens belonged to the lesser migratory species, 3 to the pellucid, and 25 to the red-legged kind. This peculiar distribution of the two migratory species was also seen elsewhere; wherever the soil was moist, or near water or swampy places, the pellucid species was more numerous.

In 1894 both species of locusts became very numerous

near Duluth, and caused considerable damage by almost denuding the lawns and gardens. They were at first most numerous in the more elevated places and upon the slopes of the hills, but as soon as the food became scarce in these localities the locusts invaded the lower portions of the city and vicinity, and destroyed almost every green thing in fields and gardens. As they reached their adult stage numerous swarms left the infested region in search of feeding grounds, and became thus established in many localities south and southeast of Duluth. In this manner the region about Pine City, Rush City and Taylor's Falls became infested. During the year 1895 some 230 hopper-dozers were operated near the places mentioned above, which required 95 barrels of kerosene oil. The work was commenced rather late, but was successfully performed, and nearly all the crops were saved. Of course the use of hopper-dozers is only a makeshift; the proper remedy is the plowing of all land containing eggs, as will be explained elsewhere. In 1897 locusts were again rather numerous near North Branch, but only the lesser migratory species (*atlanis*), the pellucid one having entirely disappeared.

Mr. E. B. Forbes, who took charge of the work in the absence of the entomologist, reported as follows: Mr. Hovton, of North Branch, Isanti Co., reported on June 17 locusts in destructive numbers in an old rye field belonging to a farm not in operation. The field had not been plowed since the spring of 1895. The locusts had spread from here in all directions but principally across a road to the south, and into fields containing rye and wheat. At that place they had spread over 200 acres, and commenced to cause injury. The farmers were very much excited, and had hauled several loads of straw onto the grass and brush separating the old field from the growing grain. The locusts had collected in considerable numbers on this straw and many were burned with it. In a number of other places locusts had also hatched in large numbers in old and unplowed fields,

and spread thence to cultivated ground. Hon. Aug. Anderson, of Taylor's Falls, had two dozen hopper-dozers made at that place and shipped to North Branch. Here these machines and about 100 gallons of kerosene oil were used with good results for a short time. The farmers were advised in the Isanti county papers to plow all fields in the infested neighborhood.

HOW LOCUSTS DEPOSIT THEIR EGGS.

It is very important to know the manner and localities in which eggs are laid by the different kinds of locusts, because the only true and always successfull remedy depends almost entirely upon this knowledge. In former papers the method of laying eggs by the Rocky Mountain Locust was discussed, but it is best to repeat and enlarge upon what was written at that time. The following figures will illustrate the method of egg-laying better than words. The holes for the reception of the eggs are made by means of two pairs of horny valves at the tip of the abdomen of the female (Fig. 2, b and c). These open and shut rapidly, and are well adapted to execute this function. The female, pressing the tip of her abdomen forcibly against the soil, rapidly opens and shuts these hard and pointed valves, and soon pushes them into the ground, thus drilling a hole. Fig. 3 illustrates this action, and the various positions assumed by the female are plainly indicated. In a short time nearly the entire and greatly extended abdomen is inserted in a little curved and more or less oblique cavity. The legs are hoisted above the back during the operation of drilling this hole, which requires more or less time, depending entirely upon the condition and character of the soil. As soon as the hole is finished, it is filled with a frothy and mucous material. Professor Riley, in describing the method

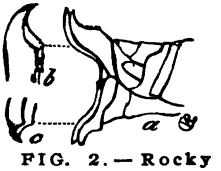


FIG. 2. — Rocky Mountain Locust—a, anal characters of female showing horny valves, b, and c. (After Riley).

of laying eggs, writes: "By repeatedly extracting and studying specimens in every stage of oviposition, we have been able to ascertain the exact method by which the egg-mass is formed. If we could manage to watch a female

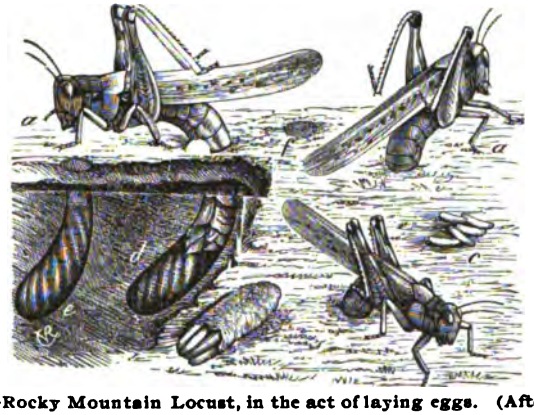


FIG. 8.—Rocky Mountain Locust, in the act of laying eggs. (After Riley).

from the time the bottom of her hole is moistened by the sebific fluid, we should see the valves all brought together, when an egg would pass down the oviduct along the ventral side, and, guided by a little finger-like style, pass in between the horny valves, and issue at their tips amid the mucous fluid already spoken of. Then follows a period of convulsions during which more mucous material is elaborated, until the whole end of the body is bathed in it, when another egg passes down and is placed in position. These alternate processes continue until the full complement of eggs are in place, the number ranging from twenty to thirty-five, but averaging about twenty-eight. The mucous matter binds all the eggs in a mass, and when the last is laid, the mother devotes some time to filling up the somewhat narrower neck of the burrow with a compact and cellular mass of the same material, which, though light and easily penetrated, is more or less impervious to water, and forms a very excellent protection. When fresh the mass is soft and moist, but it soon acquires a firm consistency.

To the casual observer, the eggs of our locust appear to be thrust indiscriminately into the hole made for their reception. A more careful study of the egg-mass, or egg-pod, will show, however, that the female took great pains to arrange them, not only so as to economize as much space as possible, consistent with the form of each egg, but so as to best facilitate the escape of the young locust; for if, from whatever cause, the upper eggs should fail to hatch, or should hatch later than the lower ones, the former would offer an impediment to the exit of the young in their endeavor to escape from these last, were there no provision against such a possibility. The eggs are, indeed, most carefully placed side by side in four rows, each row containing seven. They oblique a little cross-wise of the cylinder (Fig. 4, *a*). The posterior or narrow end, which issues first from the oviduct, is thickened, and generally shows two pale rings around the darker tip (Fig. 4, *b*). This is pushed close against the bottom of the burrow, which, being cylindrical, does not permit the outer or two side rows to be pushed quite as far down as the two inner rows, and for the very same reason the upper or head ends of the outer rows are necsesarily bent to the same extent over the inner rows, the eggs when laid being somewhat soft and plastic. There is consequently an irregular channel along the top of the mass (Fig. 4, *c*.) which is filled only with the same frothy matter that surrounds each egg, which matter occupies all the other space in the burrow not occupied by the eggs. The whole plan is seen at once by a reference to the accompanying figure, which represents, enlarged, a side view of the mass within the burrow (*a*) and a bottom

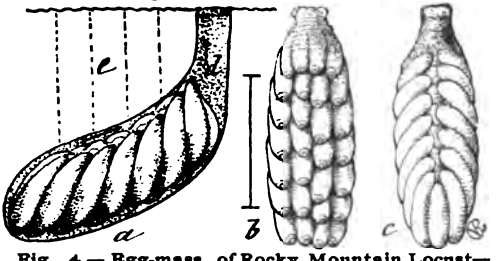


Fig. 4.— Egg-mass of Rocky Mountain Locust— *a*, from the side, within burrow; *b*, from beneath; *c*, from above; enlarged. (After Riley).

(*b*) and top (*c*) view of the same, with the earth which adheres to it removed.

Each female of the Rocky Mountain locust lays on an average about three egg-masses; this is done at intervals of two weeks, so that the egg-laying season extends from six to eight weeks.

The egg is surrounded by a shell consisting of two layers, of which the outer one is thin, semi-opaque, thus producing the creamy-yellow color; highly magnified it appears (Fig. 5. *a*) densely and minutely pitted or rather marked by hexagonal concavities (Fig. 5, *b*). The inner and thicker layer is deep yellow, smooth and translucent, so that the form of the embryo can be plainly seen when maturing inside. The outer layer is quite brittle, but the inner one very tough, requiring a strong pressure to rupture it. As the embryo within matures (Fig. 5, *c*), the egg-shell becomes weakened, and the egg plump and somewhat more transparent. By the muscular efforts of the enclosed insect, but chiefly by thorns arming the hind tibiæ, Fig. 5, *e*, the shell is eventually broken, and the young locust pushes its way through the neck of the burrow towards the light.

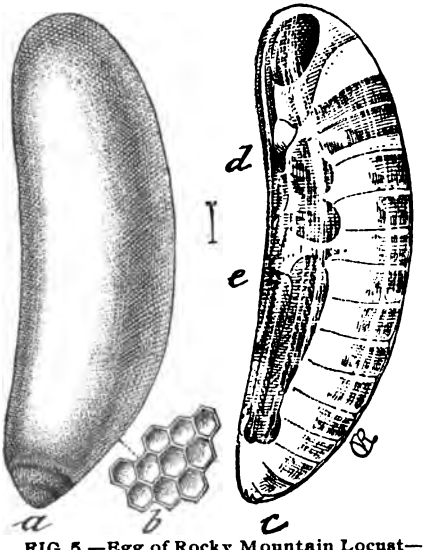


FIG. 5.—Egg of Rocky Mountain Locust—*a*, showing sculpture of outer shell; *b*, the same very highly magnified; *c*, the embryo, just before hatching. (After Riley).

Nearly all the eggs in a pod hatch at the same time, and the young escape through the small hole left for this purpose. When the young insect reaches the surface it is quite weak, and still surrounded by a very delicate film, which has to be first

removed before the young locust can jump about. By contracting and expanding muscular movements this enveloping film splits along the middle of the back, near the head, and is gradually pushed backwards, remaining as a white crumpled pellet behind. At first pale and colorless, the young locust assumes its dark color in the course of an hour.

From this account of the hatching process, we can readily understand why the female in ovipositing prefers compact or hard soil to that which is loose. The harder and less yielding the walls of the burrow, the easier will the young locust crowd its way out.

Though the covering which envelopes the little animal when first it issues from the egg is quite delicate, it nevertheless, in the struggles of hatching, undoubtedly affords much protection, and it is an interesting fact that while, as we have seen, it is shed within a few minutes of the time when the animal reaches the free air, it is seldom shed, if, from one cause or another, there is a failure to escape from the soil, even though the young locust may be struggling for days to effect an escape.

While yet enveloped in this pellicle, the animal possesses great forcing and pushing power, and if the soil is not too compact, will frequently force a direct passage through the same to the surface, as indicated by the dotted lines (Fig. 4, *e*). But if the soil is at all compressed it can make little or no headway, except through the appropriate channel (Fig. 4, *d*). While crowding its way out, the antennæ and four front legs are held in much the same position as within the egg, the hind legs being generally stretched. But the members bend in every conceivable way and where several insects are endeavoring to work through any particular passage the amount of squeezing and crowding they will endure is something remarkable. Yet if by chance the protecting pellicle is worked off before issuing from the ground, the animal looses all power of further forcing its way out. The in-

stinctive tendency to push upwards is also remarkable. In glass tubes, in which eggs were hatched in order to watch the young, these last would always turn their heads and push towards the bottom whenever the tubes were turned mouth downwards; while in tin boxes, where the eggs were placed at different depths in the ground, the young never descend, even when they were unable to ascend on account of the compactness of the soil above.

The above minute account of the manner in which eggs are laid, and how the young are enabled to reach the surface, plainly indicates one good method by which the hatching of the eggs may either be prevented entirely, or by which the young may be prevented from reaching the surface. By plowing the fields containing eggs of the Rocky Mountain locust, we perform two operations: first of all we remove the eggs from near the surface and cover them with five or six inches of soil; secondly, we invert the position of the hole containing the egg-mass, so that instead of its mouth pointing upwards, it now points downwards. At all events, the young insects are prevented from reaching the surface, if this becomes compacted by rain and snow. Consequently if we plow during autumn or soon after the eggs are laid we are safe; although if we plow in the spring with a normal amount of rain, we also effectually prevent their hatching. Plowing has this additional advantage: the egg-masses in many cases are thoroughly broken up, the individual eggs become surrounded by earth and moisture, and being no longer protected by the water-proof coat of dried mucous matter, they soon rot and perish.

To repeat again: If we desire to get rid of the migratory species of locusts now infesting several places in the state it is absolutely necessary to plow every inch of the cultivated ground throughout the invaded region or all land in which eggs have been laid.

The Lesser Migratory Locust lays its eggs in essentially the same manner. It always prefers, however, old stubble

fields, bare spots in timothy fields and neglected and dry pastures. In other words well drained spots free of vegetation, and consequently a soil free of roots, are preferred.

The Pellucid Locust has different habits as far as egg-laying is concerned. The females of the pellucid locusts commence to deposit their eggs about the end of July, usually at least fourteen days later than the other migratory kinds. Their method of doing so is entirely different. As a general rule they select for this purpose pasture land, road sides, or, by preference, clearings from which the stumps have not yet been removed, although the land has already been used for crops. In such places large numbers of eggs are deposited in the sod. Usually they are placed right upon the surface of the soil, where they are protected by the grass and by the rubbish found in such situations (Fig. 1, *b* and *c*). Occasionally the eggs are deposited just beneath the surface, but only where the ground is sufficiently loose to enable the insects to do so. The eggs are about 4 mm. in length, and 1 mm. in diameter; they are slightly curved and rounded at the ends (Fig. 1, *a*). They are deposited in layers, each with three or four eggs, which overlap and appear somewhat irregular (Fig. 1, *b*). These diagonally overlapping layers are built up until an elongated cylindrical mass from 10 to 15 mm. in length is formed. This whole mass of eggs is protected by a water-proof covering composed of bits of earth cemented together with the frothy material produced by the mother insect at the time the eggs are deposited and arranged by her. One end of this protective layer of waterproof material is very thin, almost or entirely open, thus affording the young and weak locust an easy means of egress. Each cylindrical capsule contains about twenty eggs. In many places, in which the locusts had been very numerous, in a square inch of sod were found as many as six egg-masses, which means 17,000 eggs to the square foot, enough to make crops in their vicinity a very problematical affair.

REMEDIES AGAINST LOCUSTS.

As has been stated before, the only method to reduce and destroy these injurious insects, that promises success, is the plowing of all the land in which eggs have been deposited. And in this case, as in so many others, where measures are directed against destructive insects, concerted action is all-important. If one farmer does this work in a careful manner, and his neighbor refuses to plow up a piece of meadow land filled with eggs, all the work of the one farmer will be more or less performed in vain, as the other careless one can breed upon his land enough locusts to destroy the crops of many of the surrounding farms. We still lack laws that in a case like this can force the negligent farmer to do his part of the work to get rid of such dangerous intruders, and unless such laws are made and enforced, no uniformly good results can be expected from any methods that might be applied to rout the enemy.

Since the method employed to kill the locusts depends almost entirely upon the question: Can young insects reach the surface of plowed fields, or not? It was very important to make some experiments to be able to give a positive reply to that question. To do so eggs of locusts (*spretus and atlanis*) were planted at different depths in flower pots which contained soil similar to that from which the eggs had been removed. The result of these experiments may be learned from the table below.

SOIL KEPT DRY.

Eggs planted	1	inch	below	surface	produced	93	per	cent	of	locusts.
" "	2	inches	"	"	"	86	"	"	"	"
" "	3	"	"	"	"	51	"	"	"	"
" "	4	"	"	"	"	13	"	"	"	"
" "	5	"	"	"	"	02	"	"	"	"
" "	6	"	"	"	"	none	"	"	"	"

SOIL MOISTENED FROM TIME TO TIME.

Eggs planted	1	inch	below	surface	produced	87	per	cent	of	locusts.
" "	2	inches	"	"	"	43	"	"	"	"
" "	3	"	"	"	"	11	"	"	"	"
" "	4	"	"	"	"	01	"	"	"	"
" "	5	"	"	"	"	none	"	"	"	"
" "	6	"	"	"	"	"	"	"	"	"

All the eggs experimented with were in pods, which were in no way injured or broken.

To guard against any lateral movements of the young locusts, and to prevent them from reaching the surface of the soil near the sides of the pots, where cracks in the soil would naturally form by contraction of the earth, the surface of this part of the soil was covered with a tight fitting ring of oiled cardboard. All the egg-pods were carefully planted in or near the center. Lifting up later the ring of cardboard, many locusts were found under it, showing that they had tried hard to reach the surface by digging in a horizontal direction towards the least compressed soil.

One thousand eggs, either single ones or in twos and threes, but all free from any mucous covering, were planted to a depth of one inch and a half. The soil above them was gently compressed and kept moist. Only 103 young locusts managed to reach the surface. As this happened while the writer was away from the office, he can not be certain whether or not some of them came up from below the ring of cardboard near the inner rim of the flower pot, this board having warped considerably on account of the moisture of the soil.

Early in July, after all the experiments had been finished, the soil from the various flower pots was thrown into a large box and was thoroughly loosened with the fingers. In consequence of this seven young locusts made their appearance, showing that some of the eggs, or of the young insects, had retained their vitality up to that time.

PLOWING. The chief and safest method to combat locusts consists in plowing the land known to contain their eggs. By carefully investigating the suspected fields in a number of places an approximate knowledge can be gained as to the number of eggs they contain. If a field has thus been ascertained to contain eggs it should be plowed at least five to six inches deep. If done properly, and in time, the very great majority of eggs are prevented from hatching, or

rather the young locusts hatched are prevented from reaching the surface. The best time to plow the fields is the autumn, as by doing so the surface of the plowed fields becomes hardened by the rains and snows of winter, and the egg-pods and single eggs are thoroughly surrounded by earth washed around them. Early in spring is also a good time, providing the plowing is followed by the usual spring showers. But even if no rain should follow the plowing the more or less violent winds of spring will smooth and make the soil compact, sufficiently so to prevent the great majority of young locusts from reaching the surface. Of course the plowing must be done thoroughly; simply scratching the surface of the infested field is of but slight use, though even then many egg-pods are torn to pieces and numerous of the now unprotected eggs are destroyed.

If large fields are thus plowed we secure another advantage: in case locusts should reach the surface they find no food, and before they can walk to other fields covered with plants, they starve.

Plowing is an excellent remedy even after the locusts have hatched and reached the surface. In such a case plowing should commence at the outer edge of a field, and a number of plows should be used at the same time, the plows following each other as closely as possible. The locusts are in this manner forced towards the center of the field, where a black mass of struggling insects is crowded together. But few of them escape; as one plow makes a furrow, this is rapidly filled with locusts, the following plow covers them up, and most are buried alive; those that escape this fate have to starve, and only a few near the edges of the field can save their lives.

BURNING.—In many places, where the eggs are not numerous enough to warrant plowing, all the old stubble and dead grass, etc., should be preserved until the locusts hatch. After plowing around such fields to prevent the escape of the fire, the enclosed space can be burned over

if there is enough fuel to do so thoroughly, and if a fair wind is blowing at the time, untold numbers of locusts are killed. Whenever straw can be had it is wise to make long rows of such material across the fields and thus add to the autodafe.

COLLECTING THE EGGS.—The Rocky Mountain locust prefers certain places for the purpose of depositing the eggs, and such places are easily discovered. If this is the case the eggs should be collected and destroyed, and the state should offer some inducement in the way of bounty for such collection and destruction. Every bushel of eggs destroyed is equivalent to a hundred acres of grain saved, and when we consider the amount of destruction caused by the young, and that the ground is often known to be filled with eggs, or that, in other words, the earth is sown with the seeds of future destruction, it is surprising that more laws have not been made looking to their extermination.

One of the most rapid ways of collecting the eggs, especially where they are numerous and in light soil, is to slice off about an inch of the soil by trowel or spade, and then cart the egg-laden earth to some sheltered place, where, after being allowed to dry, it is sieved, so as to separate the egg-masses from the dirt. The eggs thus collected can be easily destroyed by throwing them into deep pits, providing the ground is packed hard on the surface. In Algeria, a country badly infested with locusts, the soldiers are often employed to gather eggs, and owing to a bounty paid for all eggs thus collected, immense numbers of them are gathered and destroyed.* The same is the case in southern Russia. In thickly settled regions, where labor is abundant and cheap, this method should be adopted.

POISONING.—There are cases where plowing can not be performed, notwithstanding the fact that numerous eggs have been deposited in the ground. Frequently old timothy-fields are badly infested, but as the farmers need the grass for

*In 1897, 322 miles of ditches were constructed, in which were killed 270,000 bushels of young locusts.

their stock such fields can not be plowed. The same is true with pastures. In this case it is best to poison the plants growing on the edges of adjoining grain-fields; a strip ten feet wide is usually sufficient. The locusts, driven away by the animals in the enclosed pastures, gradually reach the poisoned plants outside and are soon killed. The best material for this purpose, and the one that has been used in a number of cases with marked success, is London purple. It is best simply because it is light, and sticks better to such smooth plants as wheat, etc., than the heavier Paris green.

Poisoning locusts in gardens and fields from which chickens and cattle can be kept away, may also be resorted to with good results, using bran-mash as poisoned bait. This is made by thoroughly mixing Paris green or London purple with dry rye or wheat bran, about one and one-half to two pounds of the poison to twenty-five pounds of bran is a good proportion; to this is added enough water to form a mash thick enough to be formed into balls without falling apart when laid upon the ground. Frequently cheap molasses is added to keep the mash from becoming too dry. Such balls are laid among the plants that we wish to protect. If an army of young locusts is moving towards a field it can be stopped and almost annihilated by offering them this food, which seems to have a wonderful attraction, as the balls are soon covered by struggling insects all eager to devour it. The consequence to them can be imagined.

CATCHING BY MEANS OF "HOPPER-DOZERS" AND OTHER MACHINERY.—The "hopper-dozers" mostly used are made as follows: A sheet of ordinary sheet iron, such as is used for making stove-pipes, is turned up one and one-half inches around the edges and riveted at the corners. This makes a shallow pan about eight feet long, two feet broad and one and one-half inches deep. To the bottom of this are riveted six small strips which can be fastened to the three runners on which the pan rests. To the rear side of the pan is screwed a light wooden frame, as long as the pan and one and one-

half feet high. Over this frame a piece of canvas is stretched. This frame serves the important office of throwing back all those locusts that otherwise jump clear over the pan, and to throw them into the oil. The runners on which the pan rests are usually made from saplings or small pieces of board having an upward curve in front to prevent them from catching in the ground. The front ends of the runners are all fastened by screws to a cross-piece which is, in turn, drawn by two ropes, one at each end. These ropes are joined in front and fastened to a single-tree. Sometimes two "hopper-dozers" are fastened to a long pole by means of short ropes; this is very easily drawn by one horse. Just in front of the pan is fastened a piece of rope which sweeps the ground a few inches in advance and serves to stir up the hoppers and make them jump into the pans. In the pan is laid a piece of cloth, which is first thoroughly saturated with water. About a pint of kerosene oil is then thrown in and the upright sheet or sail of canvas is also moistened with it. The machine is drawn over the fields or wherever the locusts are thickest. In a short time it is usually partially filled with dead or dying insects.

The slightest touch of kerosene oil, either from the pan or from the canvas sheet behind it, means death to the locust, for the oil spreads over its body in the same way that a single drop of it will spread over a large surface of water. It seems to produce a paralysis, which is first shown by the stiffening of the legs. A very large proportion of the locusts that come in contact with the oil in the pan immediately jump out again, but they invariably die in the course of a few seconds or minutes. Fig. 6 shows a hopper-dozer in operation in a hayfield. A narrow strip is cut around the margin of the field and the hopper-dozer is drawn around in this strip, with great success. Fig. 7 shows two fastened together and drawn side by side. Figs. 8 and 9 show two other hopper-dozers more in detail so as to enable anybody, even with but little ingenuity, to make them. The nature of the ground

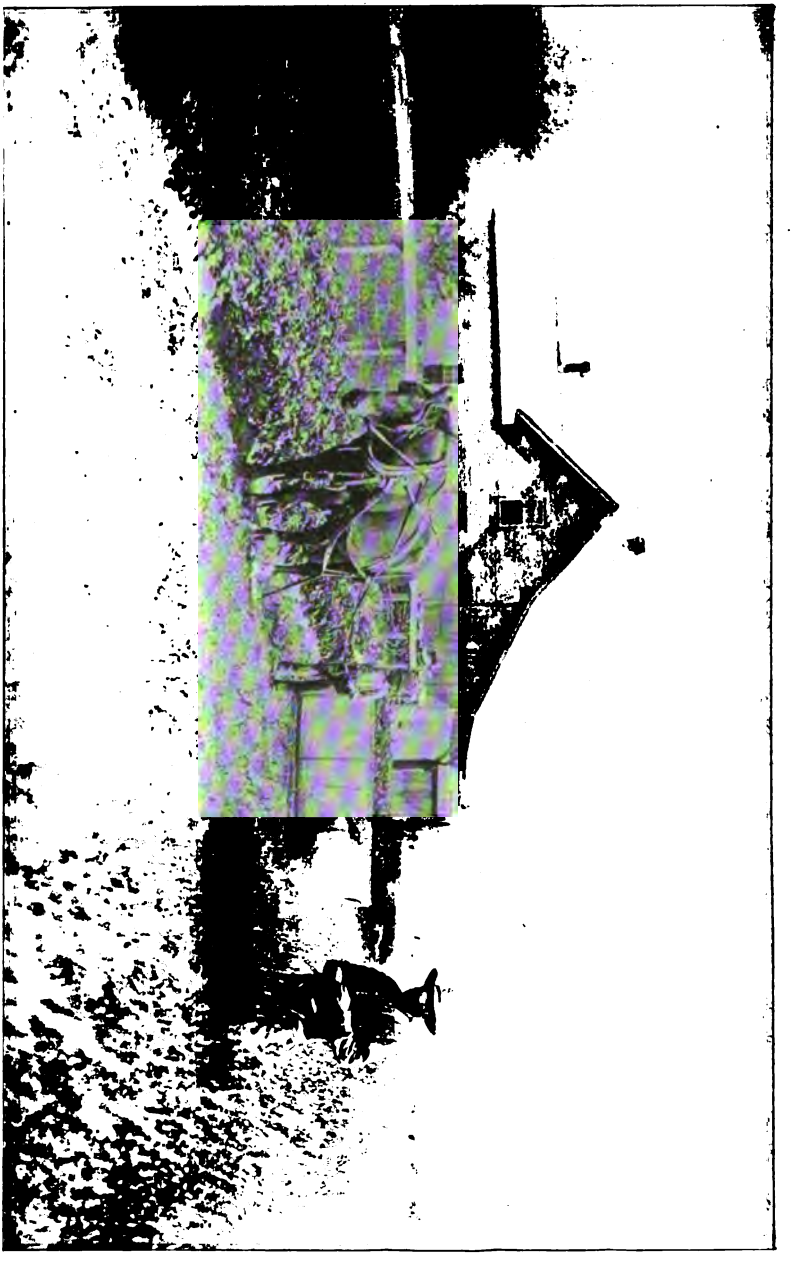


Fig. 6.—Single hopper-dozer in operation. Original.

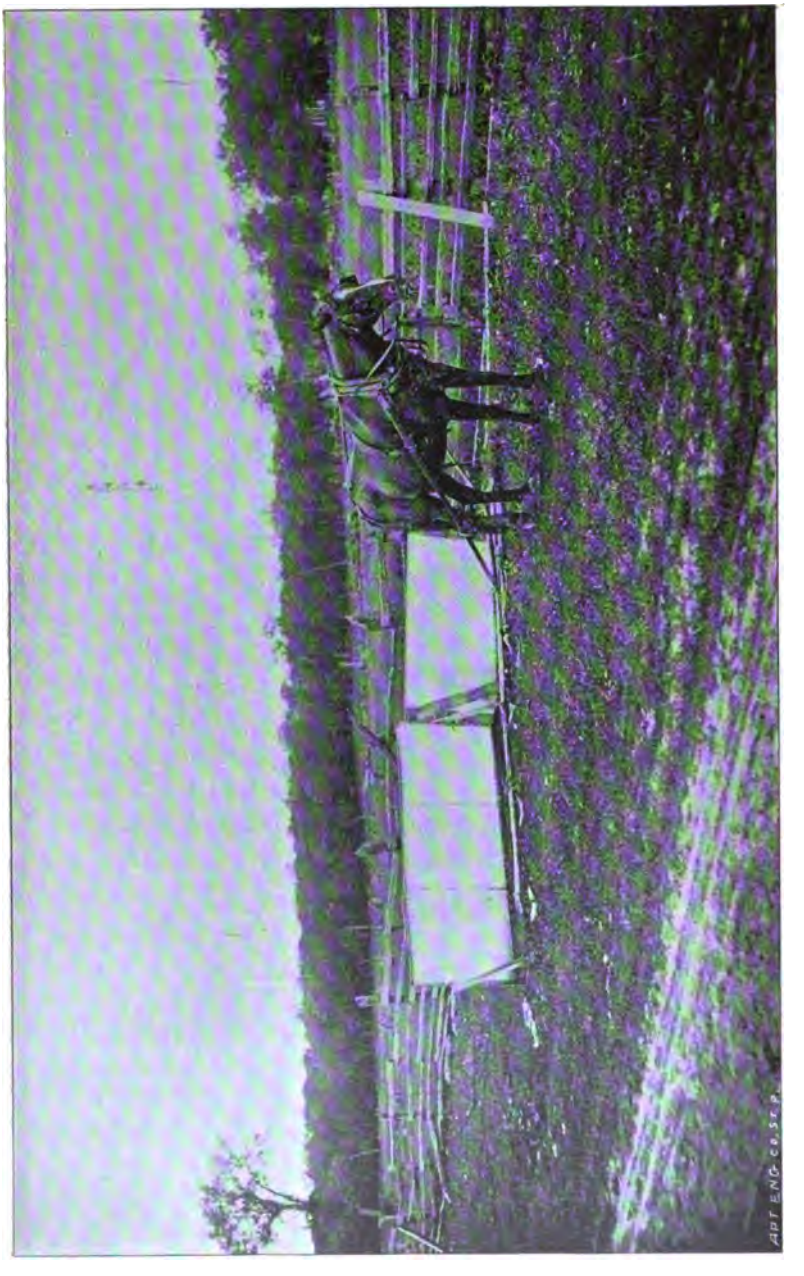


Fig. —Double hopper-dozer in operation. Original.

in the infested region does not always admit of using more than one hopper-dozer at a time. But wherever it is level and free of stones as many as four hopper-dozers can be joined together by means of short ropes, thus forming a continuous pan some forty feet long. Immense numbers of insects

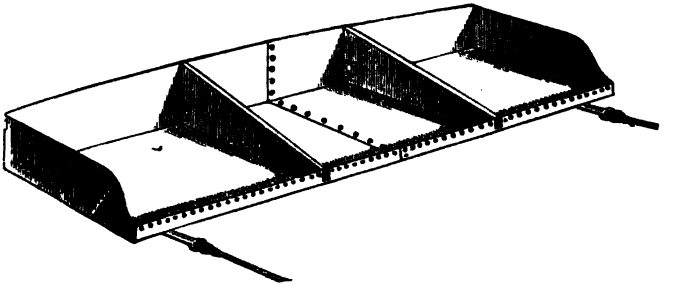


Fig. 8.—Large hopper-dozer, with partitions. After Riley.

can thus be captured and killed. Formerly a mixture of coal tar with oil, or coal tar alone, was used; this has one advantage, but only an imaginary one, i. e., the farmers operating the dozer actually see the enemy perish before their eyes, while, when using nothing but kerosene oil, only

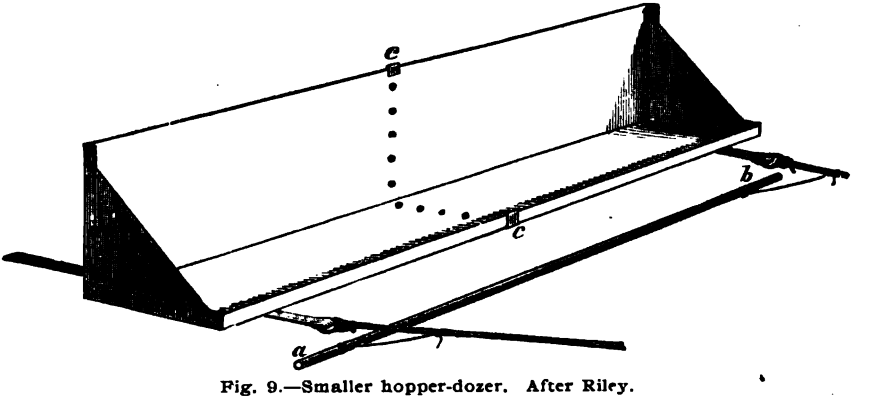


Fig. 9.—Smaller hopper-dozer. After Riley.

one out of about every ten locusts is seen dying in the pan, nine jumping out again. But as these almost invariably perish later it matters but little. As the young and tender locusts are killed whenever they come in contact with such a pene-

trating oil as kerosene still another machine has been used to some extent, and in some cases with good results. It is the "Anderson's Coal Oil Contrivance," shown in Fig. 10. It is made in the following manner: "Three pieces of

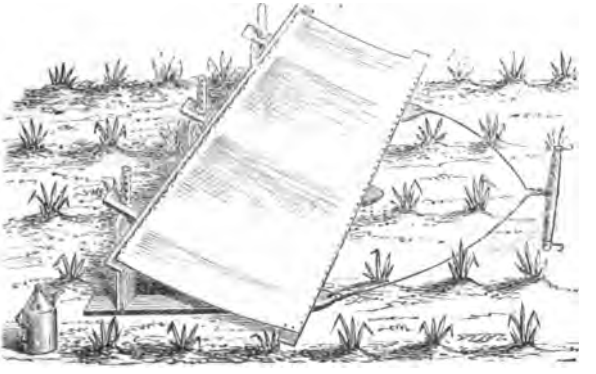


Fig. 10.—Anderson's Coal Oil Contrivance. After Riley.

fence board, four feet long and three or four feet apart, serve as sled runners. To the front ends is nailed a fence board fifteen or more feet long. To this, and over the runners, three pieces of slat, each four feet long, are attached by a leather hinge; and inch and a half holes through the back end of these slats receive light standards, the lower ends of which are fastened to the back ends of the runners by leather hinges. Peg holes in the upper half of the standards enable you to place the slats at any desirable angle. On the back ends of these slats is nailed a strip fifteen long, parallel with the fence board and three feet from it; and to these is tacked coarse muslin fifteen feet in length, which forms an apron or movable screen that can be set at any angle. To the front ends of the outside runners a long piece of fence wire can be attached, and a mule can be hitched to the wire, much to the disgust of the mule. A boy can pull the light machine, but mules pull longer than boys do." The muslin is kept soaked with kerosene oil, and as the locusts jump against it they come in contact with this death-dealing substance. An oiled locust seems to lose all power in its long

hind legs; it will stretch them out, but they soon become useless both for walking and kicking. In some localities, and on days with little wind or dust, these simple contrivances are very useful.

The use of kerosene oil has an additional advantage: it leaves behind in the field a very strong odor which is disliked by the insects, and they almost stop feeding, moving about to escape it. Of course one thing should be remembered, namely that this oil is just as deadly to plants as to locusts, hence great care should be used to prevent its spilling. In less level regions the rim of the pan should be made wider, and partitions should also be added, as shown in one of the above illustrations (Fig. 8). Smetimes instead of pulling the pan it can be left stationary, and the insects can be driven into it. This has frequently been done in fields containing numerous stumps, and with good results.

In places where the machines can not be used on account of the rough, uneven, and too sloping condition of the ground, and when cattle and chickens can be kept away, there is no better way of destroying large numbers of the locusts than by use of the poisoned baits already mentioned. There are many other machines known that can catch large numbers of locusts, but for our state, level in most parts likely to be invaded by such insects, the hopper-dozers described above are the best, and by all means the cheapest machines known.

How many locusts are really killed by a hopper-dozer is difficult to say, as nine out of the ten that jump into it jump out again, only to die afterwards in the field. But if only five or six bushels of the still small locusts are scraped off the "dozer" during a day's labor, this would mean fifty or sixty bushels killed by a single machine. This is by no means an exaggerated estimate, but if only ten per cent of these numbers were killed it would well pay for the work.

But after all, no matter how useful hopper-dozers may be against locusts and other insects feeding upon grass,

they are in the former case only a makeshift to be employed when better remedies can no longer be used. In places where they can not be employed other machines may be used, which capture the locusts in bags, or in which they are crushed by rollers, etc.

To repeat again, the true remedy consists in plowing, and wherever locusts are numerous this method has to be employed. Plow the soil containing the eggs during the autumn, if possible, as by doing so the surface of the plowed ground becomes thoroughly compact by wind, rain and snow. Plowing in spring, if well done, and as early as possible, will also be successful, though in some cases, and especially in a dry season, a few locusts may succeed in reaching the surface.

REMEDIES AGAINST COCKROACHES AND OTHER ORTHOPTEROUS INSECTS.

Remedies, or supposed remedies, against the former are very numerous, and many patented and unpatented nostrums are in the markets to help the irate housekeeper to destroy the enemy. As a general rule, however, these nostrums are only good for the dealer who sells them and the buyers. Vigilance and cleanliness are necessary to prevent the cockroaches becoming the nuisance they are now in many homes. A large number of our dwelling places are, it almost seems, built to assist the increase of this pest, by giving them lots of snug quarters in which they are safe and out of reach. Besides, these intruders, like the English Sparrow, have imported themselves to remain, and as both seem to possess great intelligence they are perfectly able to take care of themselves and to keep out of the way of servants and food doctored with poison for their benefit. Mr. F. H. Chittenden, in one of the excellent publications of the Division of Entomology, Department of Agriculture, under its efficient chief Dr. L. O. Howard, gives the following remedies:

POISONS.—"As just noted, roaches often seem to display a knowledge of the presence of poisons in food, and, notwithstanding their practically omnivorous habits, a very little arsenic in baits seems to be readily detected by them. In attempting to eradicate roaches from the department store-rooms where cloth-bound books are kept, various paste mixtures containing arsenic were tried, but the roaches invariably refused to feed on them in the least. This applies particularly to the German roach, or Croton bug, and may not hold so strongly with the less wary and perhaps less intelligent larger roaches.

A common remedy suggested for roaches consists in the liberal use of pyrethrum powder or buhach, and when this is persisted in considerable relief will be gained. It is not a perfect remedy, however, and is at best but a temporary expedient, while it has the additional disadvantage of soiling the shelves or other objects over which it is dusted. When used it should be fresh and liberally applied. Roaches are often paralized by it when not killed outright, and the morning after an application the infested premises should be gone over and all the dead or partially paralized roaches swept up and burned.

There are many proprietary substances which claim to be fairly effective roach poisons. The usefulness of most of these is, however, very problematical, and disappointment will ordinarily follow their application. The only one of these that has given very satisfactory results is a phosphorous paste, also sold in the form of pills. It probably consists of sweetened flour paste containing phosporous, and is spread on bits of white paper or cardboard and placed in the runways of the roaches. It has been used very successfully in the department to free desks from Croton bugs, numbers of the dead insects being found in the drawers every day during the time the poison was kept about.

FUMIGATION.—Whenever roaches infest small rooms or apartments which may be sealed up nearly air-

tight, and also on shipboard, the roach nuisance can be greatly abated by the proper use of poisonous gases, notably bisulphide of carbon. This substance, distributed about a pantry or room in open vessels, will evaporate, and, if used in sufficient quantity, will destroy roaches. Unless the room can be very tightly sealed up, however, the vapor dissipates so rapidly that its effect will be lost before the roaches are killed. The hatches of ships, especially of smaller coasting vessels, may be battened down, a very liberal application of bisulphide of carbon having been previously made throughout the interior. If left for twenty-four hours the roaches and all other vermin will unquestionably have been destroyed. In the use of this substance it must be always borne in mind that it is violently explosive in the presence of fire, and every possible precaution should be taken to see that no fire is in or about the premises during the treatment. It is also deadly to higher animals, and compartments should be thoroughly aired after fumigation. A safer remedy of the same nature consists in burning pyrethrum in the infested apartment. The smoke and vapors generated by the burning of this insecticide are often more effective in destroying roaches than the application of the substance in the ordinary way as a powder. There is no attendant danger of explosion, and the only precaution necessary is to see that the room is kept tightly closed for from six to twelve hours. The smoke of burning gunpowder is also very obnoxious and deadly to roaches, particularly the black English roach. On the authority of Mr. Theo. Pergande, gunpowder is commonly used in Germany to drive these roaches out of their haunts about fireplaces. The method consists in molding cones of the moistened powder and placing them in the empty fireplace and lighting them. The smoke coming from the burning powder causes the roaches to come out of the crevices about the chimney and fire bricks in great numbers, and rapidly paralyzes or kills them, so that they may be after-

wards swept up and destroyed. This remedy will only apply to old houses with large fireplaces, and has no special significance for the modern house. It is presented, however, as a means applicable wherever conditions similar to those described occur.

TRAPPING.—Various forms of traps have been very successfully employed in England and on the continent of Europe as a means of collecting and destroying roaches. These devices are all so constructed that the roaches may easily get into them and can not afterwards escape. The destruction of the roaches is effected either by the liquid into which they fall or by dousing them with hot water. A few of the common forms of traps and the methods of using them are here described.

A French trap consists of a box containing an attractive bait, the cover of which is replaced by four glass plates inclined toward the center. The roaches fall from the covering glasses into the box and are unable to escape. A similar trap used in England is described by Westwood. It consists of a small wooden box in the top of which a circular hole is cut and fitted with a glass ring, so that it is impossible for the roaches to escape. This trap is baited nightly, and the catch thrown each morning into boiling water. A simpler form of trap, which I am informed by E. C. Pratt is very successfully used in London, England, consists of any deep vessel or jar, against which a number of sticks are placed, and bent over so that they project into the interior of the vessel for a few inches. The vessel is partially filled with stale beer or ale, a liquid for which roaches seem to have a special fondness. In the morning these vessels are found charged with great quantities of dead and dying roaches, which have climbed up the inclined sticks and slipped off into the vessel. We have had fair success with this last method against the oriental roach in Washington, but against the more wary and active Croton bug it seems less effective.

Traps of the sort described, placed in pantries or baker-

ies, will unquestionably destroy great quantities of roaches, and keep them, perhaps, more effectively in check than the use of the troublesome insect powders or the distribution of poisoned baits, especially as the latter are so often ineffective."

Prof. J. B. Smith writes that "the most satisfactory way of dealing with these insects is by means of a phosphorus paste, spread upon bits of soft bread and placed near their haunts, all other food particles being put out of reach. A short period of such treatment will usually prove effective. Almost as good is a mixture of equal parts of finely powdered chocolate and borax, dusted into the crevices where the insects hide. The mixture should be intimate, and is best made in a mortar, so that with each part of chocolate, of which the roaches are very fond, they will get also a particle of boarx, which is poisonous to them. This mixture has proved successful in many instances within my own experience, and has the advantage of being cheap as well as non-poisonous to man."

In an article on "Mexican Superstition and Folk-lore" the following recipe to get rid of coachroaches is given: "Catch three and put them in a bottle, and so carry them to where two roads cross. Here hold the bottle upside down, and as they fall out repeat aloud three *credos*. Then all the cockroaches in the house from which those three came will go away." This remedy is at all events not a costly one!

Few people are aware that cockroaches are of some use; they are a popular remedy for dropsy in Russia, and both cockroach tea and cockroach pills are known in the medical practice. Salted cockroaches are said to have an agreeable flavor—for those that like highly flavored sauces. These insects have also the one redeeming character—they will eat the festive bed bugs.

The remedies against other orthopterous insects that are injurious to agriculture, etc., will be given under the descriptions of the insects, hence it is not necessary to repeat them here.

PARASITES AND OTHER ENEMIES OF LOCUSTS.

Locusts have a large number of parasitic enemies, and whenever locusts, as hosts, become at all numerous, their parasites become equally and more numerous, and soon gain mastery. This struggle for existence is constantly going on; it is a very cruel one, as no pardon is asked nor given. This is of course a good thing for the farmer, as without it all the labor he performs to rid his fields of such intruders would be performed in vain. When locusts become very numerous it seems as if they became weaker and predisposed to catch any disease that is liable to attack them, and they soon succumb. Especially a bacterial disease is very effective, and carries off many, even nearly all locusts in a given region. But this takes place only when the climatic conditions have been such as to have weakened the vitality of these insects. Continuous rain is very injurious to such sun- and warmth-loving beings. During rain locusts hide and take no food, hence a long continued spell of rain does not alone injure their constitution, but also forces them to a long abstinence from food, a condition very bad for such hungry and greedy beings.

Besides such bacterial diseases others caused by higher organized plants, such as fungi, frequently occur and more than decimate the hosts of hungry locusts.

We can always be certain that in dry seasons locusts will become destructive, even very much so, simply because they are healthier, hence devour more, and as plants do not thrive as well in a droughty season we can soon see how destructive such insects can become if favored by such conditions as much sunshine and little rain. They show by their very actions their abhorrence to moisture and dampness, and towards evening all, large and small, try to escape the same by crawling upon something that is elevated or higher than the ground. During the night, when all our locusts are more or less quiet and sleeping, and do not produce such loud sounds as the grasshoppers and crickets,

they can be found upon the stalks of plants, several feet above the ground, or upon fences and outhouses, if such are accessible.

Social insects are more liable to epidemics than solitary species, for in social species a constant contact with the diseased objects as well as with the other members of the same colony greatly facilitates the spread of a disease. This explains, in part, why a disease will spread much more rapidly, and work more effectually, when insects occur together in large numbers, than when few and scattered. The same thing occurs when an epidemic of yellow fever or cholera sweeps through our land. How much more quickly and fatally it works in our cities than in thinly populated regions! Some of these diseases seem to force their victim to wander about, and thus spread them in all directions. Thus locusts attacked by the **Locust-fungus** (*Empusa grilli* Fres.), invariably climb some tall weed or grass, and cling to it long after death.

Figure 11 shows a locust (*Melanoplus bivittatus* Say), which has been attacked by the fungus and killed after it had climbed to the top of a plant. The figure shows well the frantic efforts of the locust to cling to its support. This peculiar effect of the disease to force the sick and dying insect to cling to tall plants enables its spores to infect a much wider area, as they can from this elevated position fall on the food of the locusts as well as on the locusts themselves. This fungus has also the power of throwing its spores to a considerale distance.

FIG. 11.—*Melanoplus bivittatus* killed by a fungus. Original.

Besides the minute parasites mentioned thus far, and

which belong to the vegetable kingdom, a large number of parasites, members of the animal kingdom, seem to make it their business to destroy locusts. The more important ones are given and illustrated.

THE RED-MITE. (*Trombidium locustarum* Ril.). Quite early in the spring, or as soon as the surface of the earth is dry and fairly warm, full-grown red-mites or locust-mites can be seen running over the ground in fields and gardens. They are especially common if locusts were numerous in the previous year. These friendly mites, illustrated in Figs. 12 and 13, of a vivid scarlet color, and with the peculiar gloss of silk, are well known to children, who are in the habit of calling them the "lucky spiders," very likely from the German "Glueckspinnen," because finding them in the early spring is claimed to be the certain promise of a lucky day. And no wonder, because they are only found running about on warm and dry spring days, when all nature is reviving from a long winter's rest, when the bare

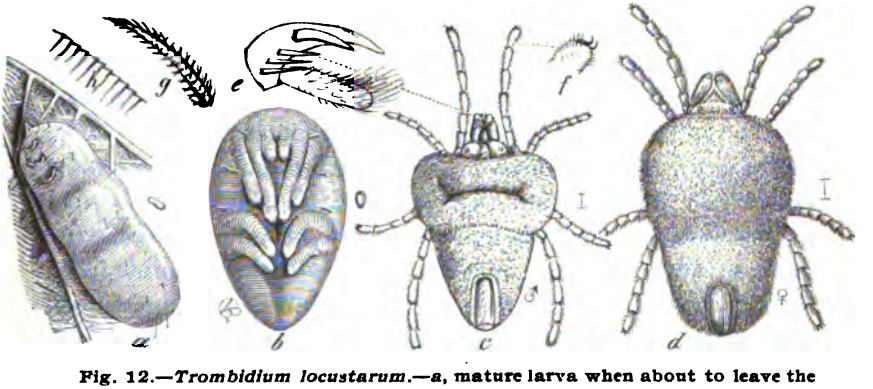


Fig. 12.—*Trombidium locustarum.*—*a*, mature larva when about to leave the wing of a locust; *b*, pupa; *c*, male adult when just from the pupa; *d*, female—the natural sizes indicated to the right; *e*, pupal claw and thumb; *f*, pedal claws; *g*, one of the barbed hairs; *h*, the striations on the larvel skin. (After Riley).

and cold ground becomes clothed in delicate green colors, and when the first flowers gladden the eyes. The illustration (Fig. 12), shows the great difference that exists between the sexes. During the spring the females deposit

from three hundred to four hundred very small, globular, orange-colored eggs, which are usually hidden in the soil at a depth of one to two inches; this is shown in Fig. 13, *a*, as well as an individual egg, *c*. These eggs soon give forth

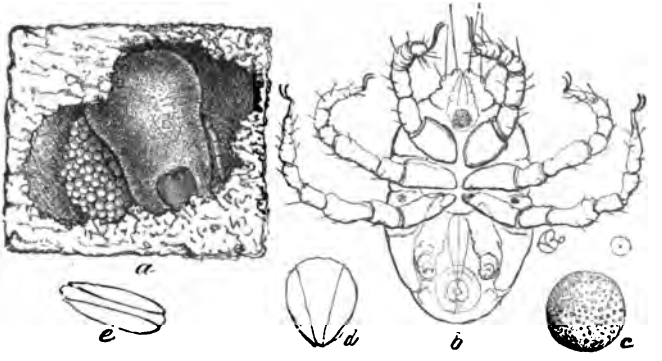


Fig. 13.—*Trombidium locustarum*.—*a*, female with her batch of eggs (after Emerton); *b*, newly hatched larva, natural size indicated by the dot within the circle; *c*, egg; *d*, *e*, vacated egg shells. (After Riley).

small orange-colored, six-legged and very active mites, fig. 13, *b*, whose aim in life seems to be to find living food, to which they fasten themselves. If they succeed in finding a locust, they fasten themselves very securely to its wings, or in case of a pupa to its wing-pads, and almost invariably to its under side. Here they use their mouth-parts so diligently, that their bodies soon swell with the life-blood of the attacked host; their former long legs become shorter and shorter in proportion, and are soon almost invisible (Fig. 12, *a*). In this condition they can, of course, no longer move about, and they look very much like minute drops of blood, or like eggs, and are frequently mistaken for such. We can well imagine that a locust thus infested by one or more of such rapid growing mites, must soon become disabled, or at least greatly weakened. To such locusts life is no longer a continuous round of pleasure, and they soon take a gloomy view of it, and refuse to join their festive brethren; they either congregate with similarly affected ones, and are thus

found in large numbers upon fences, etc., or they drag about their enfeebled bodies, separated from their relatives. When these mites, fastened to locusts, become fully grown they drop to the ground, and hide for several weeks without taking any food. Gradually the pupal state is assumed, without going through a molt, as would be the case if mites were true insects. Inside this pupa, shown in Fig. 12, *b*, the mature mite is formed. Breaking through the retaining pupal skin it appears as an eight-legged being, which passes the winter in the ground. But the mite is not idle, except when the temperature sinks below the freezing point. It feeds upon all sorts of soft food, and whenever it has access to the eggs of locusts it greedily eats them. In soil containing eggs of locusts large numbers of these mites congregate. They creep into every hole in search of these eggs and thrive upon such rich food. The great advantage of plowing over all other remedies is also seen in regard to these red-mites, as the plowing of fields in which eggs of locusts have been deposited will destroy the young locusts hatching from them, but not the mites, which can easily work their way towards the surface. Plowing destroys our enemies, but not our friends!

TACHINA-FLIES.—These beneficial flies are generally of a gray color, and resemble very much large house-flies; they are of very great assistance in killing locusts. In fields crowded with locusts they can be seen buzzing around a wide-awake hopper, who seems to know the threatening danger, as he will dodge the flies in the most excited and ridiculous manner. But all dodging and kicking proves in most cases of no avail, as the persevering fly will certainly succeed in fastening its white and elongated egg upon the neck of the victim or under its wings. The maggots hatching from such eggs eat their way into the body of the locust. Here they devour everything, frequently leaving, however, the vital organs untouched, they being, very likely, less tender than the fatty parts stored up for the formation

of future organs. If fully grown the maggots force their way through the skin of their host and drop to the ground. Here they burrow in the earth, and, contracting into brown barrel-shaped puparia, they rest awhile.

Inside this puparium, composed of the old larval skin, the true pupa is formed, and later the winged fly, which breaks through the surrounding skins and crawls towards the light of day. In a very short time it is able to use its wings, and is ready to enjoy life after its own fashion. A locust harboring such a maggot, or several of them, is less active than others, and seems to look upon life as a rather serious affair, in fact to think it a real bore. Fishermen in search of bait catch such languid locusts much more readily than healthy ones, but find, in pulling away their wings or heads, a humane way that disciples of Isaac Walton have, nothing but an almost empty shell, by no means a tempting morsel for a fish. Several species of Tachina-flies infest locusts.

Fig. 14.—*Sarcophaga carnaria* var.—*a*, larva; *b*, pupa; *c*, fly, the hair lines showing average natural length. (After Riley).

FLESH-FLY.—(*Sarcophaga carnaria* Linn.), a well known scavenger in Europe, Australia and America, is also found as a true parasite in many species of locusts. It, as well as its earlier stages, are illustrated in Fig. 14. This illustration will also show the shape, size and general appearance of a true tachina-fly, which is quite similar to it.

BEE-FLY.—(*Systœchus oreas*). When fields, meadows and pastures are inspected for the eggs of locusts the larvæ of these flies are always found, showing that these friends of the farmer are doing good work. The adult fly is illustrated in Fig. 15, the larva in Fig. 16. The beautiful flies are frequently seen towards the middle of July; they are then employed in sipping honey with their very

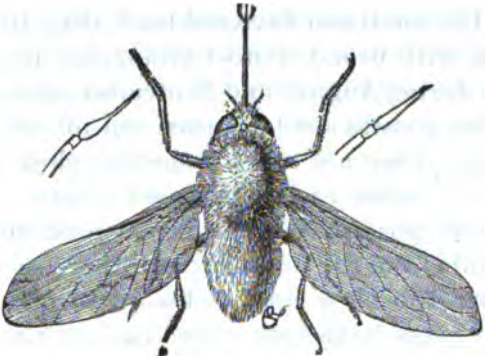


Fig. 15.—*Systœchus oreas*.—Female fly. (After Riley).

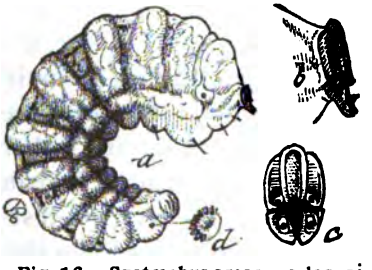


Fig. 16.—*Systœchus oreas*.—*a*. larva; *b*. head from side; *c*. head from front; *d*. preanal spiracle. (After Riley).

long proboscis from the various species of composite flowers. This proboscis can be used for other purposes than sipping nectar, as the writer found out to his sorrow, when he attempted to catch some of them with his hand, and succeeded. Violent pain, a swollen finger, and added knowledge were other results of the catch not bargained for. Early in August these flies are exceedingly numerous, hovering in the air and keeping their wings in such rapid motion that they can not be distinguished, but appear like a haze surrounding the body of the insects; when disturbed these flies will dart away with wonderful speed, to remain again stationary in the air in another spot. These bee-flies, although possessing a blackish-gray ground color, are so densely covered with pale yellow hairs, that this color is entirely hidden; this hair is so long that the outlines of the insects are obscured, and they resemble on this account very small bumble-bees.

The eggs and method of oviposition are not known. The larvæ are found among the egg-masses of the locusts; they have curved bodies, swollen in front and tapering behind; their color is opaque white with translucent yellowish

markings. The small and flattened head, (Fig. 16, *b* and *c*), is dark brown, with broad, almost triangular jaws. All the larvæ found during August and September, though varying greatly in size, possess similar forms, and all are almost unable to move. They are most frequently close to the egg-pods, which in some cases are found empty. The young maggots must possess a very different form and decidedly different habits from the adult larvæ, otherwise they would be altogether too slow and awkward to find the eggs of locusts. No pupæ have been found and all the larvæ kept in breeding cages have dried up before changing.

BLISTER-BEETLES.

Several species of Blister-beetles or Spanish-flies occur in large numbers throughout the infested region. In fact some of them cause considerable damage to potatoes and other plants. Many of these blister-beetles are known to feed in their early stages upon the eggs of locusts. A very interesting report upon the peculiar life-histories of these beetles was published in the "First Annual Report of the United States Entomological Commission." The following species of these beetles are abundant in Minnesota: the Ash-gray Blister-beetle (*Macrobasis unicolor* Kirby), the Margined Blister-beetle (*Epicauta cinerea* Forst.), the Black Blister-beetle (*Epicauta pennsylvanica* De G.), and the Red-headed Blister-beetle (*Epicauta trichrus* Pall.). All these beetles, frequently best known as being very injurious to potatoes, beans and other cultivated plants, surely have one great redeeming character, in being our best friends by checking an undue increase of noxious species of locusts. Their life-history may be summed up in a few words: they deposit, from July to October, their orange or yellow-colored eggs in irregular masses in loose ground, each female producing from four hundred to five hundred eggs. In about ten days these eggs hatch, producing very active, long-legged larvæ with large heads and strong jaws, which run about search-

ing everywhere for the eggs of locusts. If an egg-pod has been found, the larva forces its way into it and commences to devour an egg; if two larvæ have found the same prize a mortal combat takes place, lasting until a single larva remains as sole owner of this store of food. As soon as one or two eggs have been consumed the larva throws off its skin, and reappears in a very different shape, being now white, soft, and possessing only small legs. In the course of another week a second molt takes place, disclosing a larva with rudimentary mouth-parts and legs, and of a very clumsy aspect. Soon another molt takes place, but only slight changes are seen in this form of the larva. After eating the remaining eggs in the pod, and leaving it, it burrows in the soil, where it forms a smooth cavity, within which it rests. Soon it splits its skin again, disclosing now quite rudimentary, tuberculous mouth-parts and legs; the semi-pupa thus formed is rigid and of a deeper yellow color. It hibernates in this condition. In spring the skin is again torn open, and a larva appears looking like that of the second shape, but smaller and whiter; it is quite active, but does not seem to require any food. It changes into a true pupa, and eventually into a winged beetle.

Besides these species still another one with bright metallic colors, the *Cantharis Nuttalli*, is exceedingly abundant in years following locust troubles. Very likely the larvæ of this beetle possess similar habits, and are consequently very beneficial.

OTHER PARASITES AND CANNIBALS.

Quite a number of eggs of the locusts are destroyed by other true parasitic insects, one of which is illustrated in Fig. 17. It is called *Scelio Luggeri*, Ril. In some egg-pods every egg is eaten by the larvæ of this useful insect, so that instead of harboring the embryo of a locust the egg contains a small wasp. These minute insects are difficult to find, as they are not distinguished by metallic colors, which is usually the case

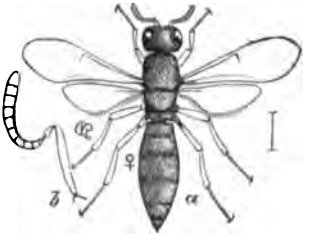


Fig. 17.—*Scelio Luggeri.* After Riley.

in allied insects, but are of a dingy black color, with honey-yellow legs. Moreover, they do not fly about actively, but rather crawl over the soil. If disturbed they jump like fleas and vanish from sight.

A large number of carnivorous insects have also been observed to assist us in reducing the numbers of locusts, either by eating the eggs or by devouring the young insects. Numerous larvæ of egg-feeding beetles occur, of which the most important ones belong to the genus *Amara*. In some fields every second egg-pod contains the larva of *Amara latior*, Kirby; if not actually inside the egg-pod it is found upon the outside of it or very close to it. Numerous larvæ of a larger species (*Amara obesa*, Say), are also found; the

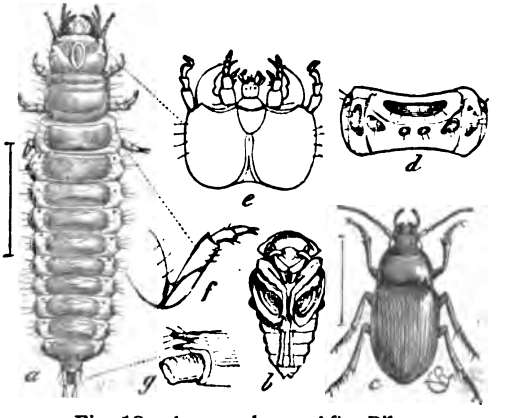


Fig. 18.—*Amara obesa.* After Riley.

illustration (Fig. 18) shows the different stages of this useful insect.

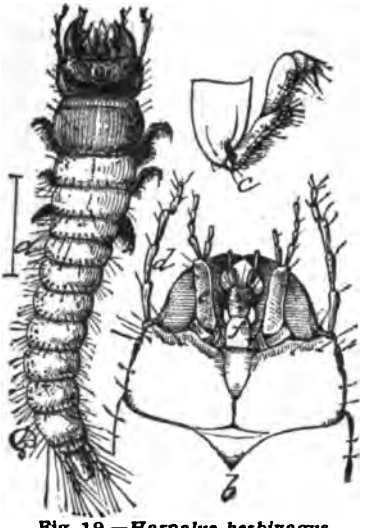


Fig. 19.—*Harpalus herbivagus.* After Riley.

Still another coleopterous larva is usually found in large numbers; it is the larva of *Harpalus herbivagus* Say, an insect very abundant in fields infested with locusts. It is shown in Fig. 19.

A very interesting little coleopterous larva is also found in considerable numbers inside of the egg-pods of locusts. It is shown in Fig. 20, and produces a small Click-beetle (*Cryptohypnus bicolor*, Esch., var. *lacustris*.

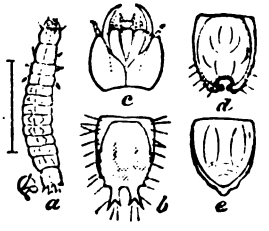


Fig. 20.—Larva of *Cryptohypnus bicolor.* After Riley.

Numerous larvæ of flies occur near the egg-masses, some of which are known to be our friends.

Very active and doing good work are also the larvæ of *Calosoma frigidum* Kirby, and of *Calosoma calidum*, Fab., the former of which is only found near edges of forests, while the latter occurs everywhere in the prairies. The mature beetles of these species feed also upon the half-grown locusts. The adult of *Calosoma frigidum* is shown in Fig. 20½. This species possesses very different habits from the other species of *Calosoma*, with the exception of *scrutator*. It climbs trees in search of the caterpillars of Canker-worms, and is as active in this work as the green species, which, owing to its protective color, is better equipped for such an arboreal life. It would not be a bad idea to utilize *frigidum* in the war against the noxious

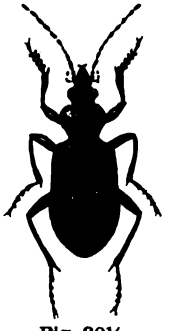


Fig. 20½. *Calosoma frigidum* Natural size. Original.

Gypsy-moth, so destructive in Massachusetts. Hiding during the day, but very active at night, are also other large ground-beetles, belonging to the genera of *Pasimachus* and *Scarites;* especially the former are very fond of young locusts and have been seen devouring them in great numbers.

Many other beetles, flies and wasps are known to feed upon locusts, or to use them as food for their young. But enough has been shown to indicate that the life of a locust is not one constant round of pleasure. This becomes very plain if we consider that besides the enemies already mentioned the locusts are badly invaded by internal parasites, for instance by that curious being, the Hair-snake (*Gordius* species). If we remove the head of a parasitized locust we sometimes see its whole interior filled with this parasite, which is many times as long as its host, and it will be seen that all the important organs of the locust are compressed and unable to perform their necessary functions, hence the insect looks "pale and sickly."

OTHER ENEMIES OF THE LOCUSTS.

A large number of birds and animals eat locusts whenever they have a chance to do so. Domestic fowls eat them greedily, but soon tire of this diet if the insects become very numerous. Most active of all in destroying locusts is a small tern, the Black Tern, (*Hydrochelidon nigra surinamensis*), which is very common in the prairies, even many miles from any water. It and the Rosy Gull (*Larus Franklini*), are constantly engaged in catching the young locusts, for themselves as well as for their young. Both species of aquatic birds follow the plow, very much in the same way as the crow is in the habit of doing elsewhere. The various species of blackbirds, such as the Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*); the Red-shouldered Blackbird (*Agelaius phoeniceus*); the Rusty Blackbird (*Scolecophagus carolinus*); the Bronzed Grackle (*Quiscalus quiscula aeneus*);

the Brewer's Blackbird (*Scoleophagus cyanocephalus*); and the Cowbird (*Molothrus ater*), all catch and eat locusts. The first four are the most active ones, especially as long as they have to provide for their young. At this period they are making constant trips from nest to field and return. A Yellow-headed Blackbird, distinguished by lacking a feather in the left wing, made thirty-seven trips per hour to a field adjoining the river, where it had its nest in a clump of cat-tails. Strange to say, later in the season, the locusts took revenge by eating off all the leaves and softer parts of the cat-tails, thus exposing the nest. As soon as the young blackbirds are able to follow their parents they all go locust-hunting. Owls and hawks also feed largely upon these insects, as the balls voided by them always contain numerous parts of locusts. Other birds no doubt also eat locusts, at least the unfledged ones. Prairie chickens have frequently been seen in the roads picking up locusts, and the same can be stated of some rails.

Animals also eat locusts, and the skunk grows fat upon this food. Even gophers do not despise a dish of tender locusts, which is also to the taste of toads, frogs and snakes.

VALUE OF LOCUSTS AS FERTILIZERS.

Locusts contain a large amount of nitrogen, and whenever they are caught on a large scale this valuable fertilizer ought to be utilized. Prof. D. N. Harper made an analysis of locusts given him for that purpose. He writes: "I report herewith the result of my analysis of the locusts handed to me for examination as to their contents for fertilizing ingredients. The locusts and the alcoholic liquor in which they were preserved were evaporated to dryness at a temperature of boiling water. They were then pulverized and thoroughly intermixed, and portions taken for analysis. This resulted as follows:

	(per cent)
Nitrogen	10.71
Phosphoric acid soluble in water	1.52
Phosphoric acid insoluble in water	.24
	1.76

The phosphoric acid in such phosphates as are insoluble in water or solution of ammonium citrate of 1.09 specific gravity is termed *insoluble phosphoric acid;* in such as are insoluble in water but soluble in ammonium citrate solution is termed *reverted phosphoric acid.* "Soluble" and "reverted" phosphoric acid are equally available by the plant as food. Insoluble phosphoric acid is not as readily available. Nitrogen is the most valuable fertilizing ingredient."

CONCLUSION.

It is possible to successfully fight and exterminate locusts, providing active measures are adopted at once, and are, moreover, carried out faithfully. This is only true, however, if we have to deal with local swarms, and not with armies covering whole states. In the former case if every one owning a farm in the infested region will only properly cultivate the same, will plow it during the fall, permit no fields to be idle, and seed it in the spring, no fears of loss need be entertained.

In describing the habits of insects, their growth and metamorphoses, as well as their relation to agriculture, horticulture and allied pursuits, it is very important and necessary to study not alone the general form of an insect, but also its external and internal anatomy. For our purpose it will be sufficient to select one member of the order of orthoptera, the common Two-striped Locust (*Melanoplus bivittatus*), and to describe in as general terms as possible the different parts of the same.

EXTERNAL ANATOMY.*

The body of a locust consists of an external thick skin, hardened and stiffened by a substance called chitine, which protects the softer organs within. Chitine is a peculiar substance found only in the teguments of articulated animals. The harder external skin is the analogue of the skeleton of the mammalia, and to it are fastened all the muscles that are necessary for the functions of an insect. As this outer skeleton must be more or less rigid, insects would not be able to move at all if it were not jointed or segmented in such a manner that each segment, or ring, is connected with the neighboring ones by a softer membrane. Each segment may be again subdivided into smaller pieces. We can observe

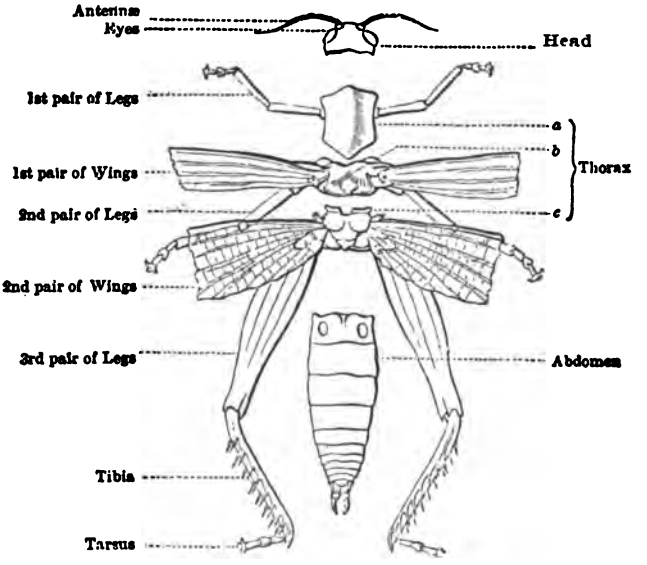


Fig. 21.—A locust dissected to show divisions of body.

such segments quite readily in caterpillars; the abdomen of the locust also shows them very distinctly, as here the seg-

*See explanation of anatomical illustrations at end of chapter.

ments are not as complicated as they are at the extremities of the body, the head and end of the abdomen. The long and narrow body of a locust, laterally compressed, is like that of all other true insects in their perfect state, divided into three well marked regions, the *head*, *thorax* and *abdomen*. The head is flattened from before backwards, and elongated vertically. It bears the eyes, the antennæ and the mouth-parts, and is movably joined, by a short neck, to the second region of the body. The thorax forms, with the head, the anterior half of the body. It carries on its lower surface the three pairs of legs, which gradually increase in size from before backward, the third pair being *much* the largest. The two pairs of wings are fastened to the posterior portion of the dorsal surface of the thorax. The abdomen, a little longer than head and thorax combined, is composed of a number of movable segments without appendages.

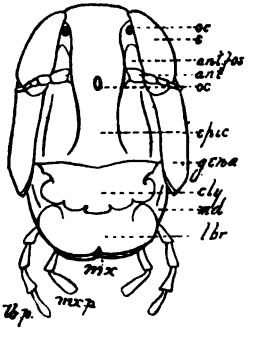


Fig. 22.— Front view of the head of *Melanoplus bivittatus*. Original.

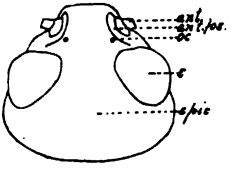


Fig. 23.—Vertical view of the head of *Melanoplus bivittatus*. Original.

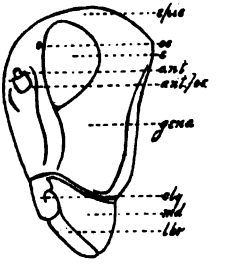


Fig. 24.—Lateral view of the head of *Melanoplus bivittatus*. Original.

THE HEAD (Fig. 22, 23, 24).—The outer or dorsal surface of the head consists of a very broad and long frontal and a much smaller and shorter occipital area. The *epicranium* (*epic*), which forms the covering of the dorsal occipital area, becomes narrow and runs downwards between

the eyes and antennæ to about the middle of the frontal area, where it enlarges again, and ends below in a prominent, straight, transverse suture. Faint lines indicate that the epicranium is formed by the fusion of two originally separate pieces. An obscure ridge between the upper ends of the eyes perhaps also indicates the union of two segments. The large projecting *compound eyes* (*e*), are oval and highly polished and are situated on the upper portion of the sides of the head. These eyes are composed of many thousands of hexagonal facets or lenses and are marked with parallel vertical bands of brown pigment. A little in front of the upper margin of each of the compound eyes is a convex oval area, in which the integument is so thin and transparent that the tissue below can be seen. These minute spots are the *ocelli* (*oc*) or simple eyes. A third ocellus can be seen between the antennæ on the median line of the epicranium. The *antennæ* (*ant*) are composed of a larger basal joint and twenty-six movable rings which increase gradually in length from base to tip. The basal joints of the antennæ are fastened to the centers of two oval areas, the *antennary fossæ* (*ant. fos*), which are located between the eyes on the narrow frontal portion of the epicranium. The antennæ can be moved in all directions. The lower and straight edge of the epicranium articulates with a wide, short plate, the *clypeus* (*cly*), the sides of which are deeply notched, showing the traces of a division into two plates. In front of this is a movable, flap-like *labrum* (*lbr*), the free edge of which is deeply notched on the median line, the remnant of the suture formed by the union of the halves or paired appendages which the labrum represents. On the side of the head is a suture, which runs from the lower anterior angle of the eye to the lower margin of the epicranium, and separates the latter from the large plate, the *gena* (*gena*), which forms the side of the head, and terminates below in a free, pointed edge. Between the lower anterior edge of the gena and the clypeus is a dark colored area, the outer surface of the basal portion of the *mandible* (*md*).

FIG. 25.—Mandibles of *Melanoplus bivittatus*; a, external view; b, internal view. Original.

By removing the labrum, the large, black-tipped, powerful, toothed *mandibles*, (Fig. 25), are seen, which meet each other on the median line; their outer ends articulate with the lower anterior edge of the gena, by a joint which allows them to move towards or away from the median line, but in no other direction. The large *occipital foramen*, by which the cavity of the head communicates with that of the neck, is bounded above by the epicranium, at the sides by the gena, and below by a crescent-shaped sternal plate, the *gula*. Movably articulated with the lower straight edge of the gula is the *labium* or lower lip (Fig. 26), formed by the union of a pair of appendages, which are immovably united, but still show upon the median lines traces of this union. The labium consists of a basal portion, the *mentum* (*m*); a pair of terminal apron-shaped pieces, convex behind and concave in front, the two halves of the *ligula* (*li*); on each outer edge of the mentum is a small piece, the *palpiger* (*palpr*), and upon this the three-jointed *labial palpus* (*lb. p*). By removing the gula and the labium the posterior faces of the anterior mouth-parts are exposed. Forming the posterior boundary of the mouth, in the median line, is a dark-colored chitinous spiny pad, the *metastoma* or tongue, which has its anterior face covered with rows of spines. Arching over the tongue and forming the anterior boundary of the mouth are the black tips of the *maxillæ* (*mx*), meeting upon the median line. Each maxilla is made up of a basal joint or *cardo* (*co*), which is directed transversely to the long axis of the head, and articulates with the lower posterior edge of the gena. The second joint, or *stipes* (*stip*), runs forward at right

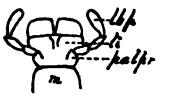


FIG. 26.—Labium or lower lip of *Melanoplus bivittatus*. Original.

FIG. 27.—Maxilla of *Melanoplus bivittatus*. Original.

angles to the cardo and parallel to the long axis of the head. It is movable towards and away from the median line. The *maxillary palpus* (*mx. p*) is carried upon the outer angle of the stipes, and is made up of two short and three long joints. The *lacinia* (*lac*), the toothed black-tipped cutting portion of the maxilla, is carried upon the inner margin of the distal end of the stipes The *galea* (*ga*), or soft, brown, spoon-shaped portion of the maxilla, is carried upon the outer angle of the stipes and bends around in front of the lacinia. The illustration, (Fig. 27), shows the different parts described above.

THE THORAX.—To study the thorax, the legs and wings should be removed. It will be seen that the thorax is made up of three segments, each of which bears a pair of legs. These three segments are known as the *prothorax* (*pro*), *mesothorax* (*meso*), and *metathorax* (*meta*). The prothorax, (Fig. 28), has the sides and dorsal surface covered by a large, sun-bonnet shaped piece, the *pronotum* (*n*). The dorsal portion of the pronotum is prolonged backwards along the median line and partially overlaps the second division or mesothorax. The anterior portion of the pronotum is crossed by three grooves or sutures, which divide it into four immovably united pieces; the first of these forms the anterior margin of the pronotum, and is called the *prothoracic prescutum* (*p. sc*); the second is the *prothoracic scutum* (*sc*); the third the *prothoracic scutellum* (*scl*), and the last the *prothoracic postscutellum* (*p. sel*). The ventral portion of the prothorax, (Fig. 29), is formed by a slender, movable *sterum* (*st*), which connects the sides of the pronotum with each other. On the median line it carries, in this species, a large club-shaped spine (*pro. sp*). Near the outer ends of the sternum are the fossæ for the attachment of

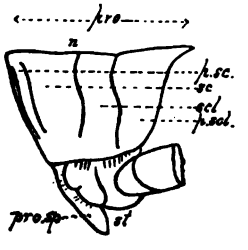


FIG. 28.—Lateral view of the prothorax of *Melanoplus bivittatus*. Original.

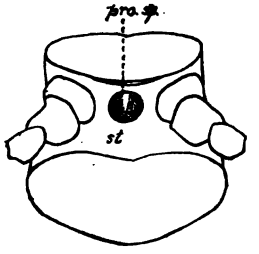


FIG. 29.—Ventral view of the prothoracic sternum of *Melanoplus bivittatus*. Original.

the limbs. The mesothorax and metathorax are much more complicated, and together with the first abdominal segment, are soldered into a firm-walled box. The flattened ventral surface of this box is made up of three pieces; the *mesosternum* (*meso. st*), which consists of an anterior median portion and two nearly rectangular posterior prolongations; the *metasternum* (*meta. st*) is a somewhat larger plate, which consists of an anterior square tongue filling the space between the posterior horns of the mesosternum, and a large pentagonal portion. The first abdominal sternum (*1st abd. st*) is morticed into the posterior margin of the metasternum in nearly the same way that the latter is joined to the preceding sternum.

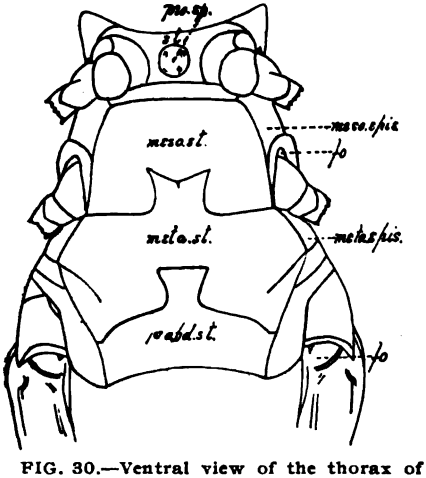


FIG. 30.—Ventral view of the thorax of *Melanoplus bivittatus*. Original.

In this ventral view of the thorax, (Fig. 30), the lower ends of the episterna and the fossæ (*fo*) for the articulation of the legs, are visible at the sides of the sterna. Parallel with the anterior half of the mesosternum are the lower ends of the *mesothoracic episterna* (*meso. epis*). Parallel with the posterior half of the mesosternum are the fossæ of the second pair of legs. The inner borders of these fossæ are not formed by the mesosternum itself, but by slender horn-like backwards prolongations of the lower end of the episternum. Parallel with the anterior

half of the metasternum are the lower ends of the *metathoracic episterna* (*meta. epis*), separating the fossæ of the second legs from those of the third and sending prolongations backwards to form the inner margins of the latter.

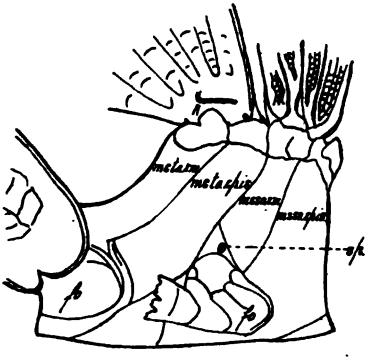


Fig. 31.—Lateral view of the thorax (*pleurites*) of *Melanoplus bivittatus*. Original.

In a side view of a thorax, (Fig. 31), from which the pronotum, wings and legs have been removed, the space above the leg fossæ is occupied by four rectangular pieces, which slope obliquely upwards and forwards. The anterior margin of each of these is marked by a dark stripe or band of pigment, and the posterior margin by a light stripe. The first or most anterior piece is the *mesothoracic episternum* (*meso.epis*). Its lower margin is prolonged downwards and backwards and forms the anterior and lower boundary of the fossæ of the second leg. The second piece is the *mesothoracic epimeron*, (*meso. em*). Its lower end forms the upper and posterior margin of the leg fossæ. The third piece is the *metathoracic episternum* (*meta. epis*). The fourth is the *metathoracic epimeron* (*meta. em*). Between the metathoracic epimeron and metathoracic episternum, just above the mesothoracic leg fossæ, is a small oval aperture provided with a pair of lip-like chitinous valves. This is the respiratory aperture or *spiracle*, (*sp*) of the metathoracic segment. Along the upper margins of the episterna and epimera are a few small, irregular pieces, to which the wings are articulated. The dorsal surface of the meso-and metathorax, (Fig. 32), is formed by two nearly square areas, which occupy the space between the wings. They are soft and membranous, and the pieces which compose them are not sharply defined. The anterior

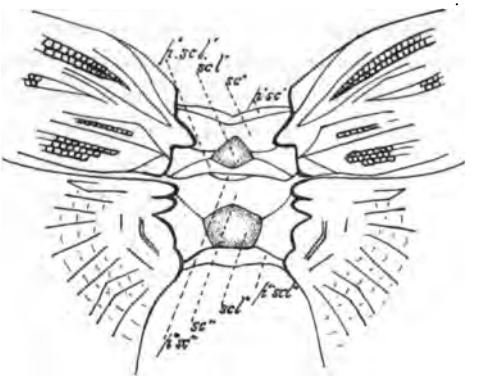


Fig. 32.—Dorsal view of the meso-and metathorax of *Melanoplus bivittatus*. Original.

border of each is formed by a narrow plate, the *prescutum*. Back of this is a large, convex, dark-colored, glistening surface, the *scutum*. Behind the scutum is a membranous piece upon the median line, the *scutellum*. The posterior margin is occupied by a long, narrow, light-colored piece, the *post-scutellum*.

THE WINGS.—The anterior or upper pair of wings (Fig. 33), named *tegmina* or *wing-covers*, are about as long as

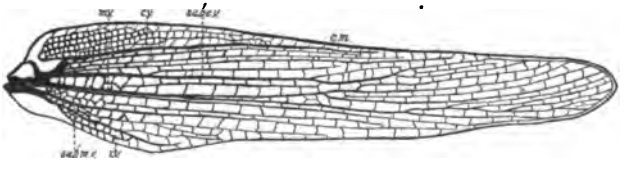


Fig. 33.—Tegmina, elytra or wing-cover of *Melanoplus bivittatus*. Original.

the body, beyond the posterior end of which they project. They are narrow and the anterior and posterior margins are seen, when the wing is extended, to be nearly parallel. When folded upon the body their outer faces are vertical, with the anterior margin below, and the posterior or *internal* edges in contact along the back, the left slightly overlapping the right. Each wing-cover is a thin, transparent, rather stiff plate of chitine, marked with a yellowish-brown stripe. It is strengthened by a network of chitinous tubes,

the *veins*, of which there are five on each wing, diverging from the proximal end of the wing, and giving rise to smaller veins. These in turn divide into much smaller *veinlets*, which inosculate with each other and divide the surface of the wing into small, irregular polygonal areas or *cells*. The vein nearest the anterior or *costal* margin (*c. m*) of the wing is the *costal vein*, (*c. v*). It is undivided and may be traced for a little more than half the length of the wing. The second very much larger vein is the *sub-costal* (*sub. c. v*). It gives rise to several large branches, the subdivisions of which form the framework of the greater part of the wing. The third or *median* (*m. v*) is much smaller and soon divides into two branches of nearly equal size. The remaining pair, which are known as the *sub-median*, (*sub. m. v*) and *internal* (*i. v*), run close to and parallel with each other near the internal or posterior margin of the wing. The tegmina is divided by these veins into three areas. The

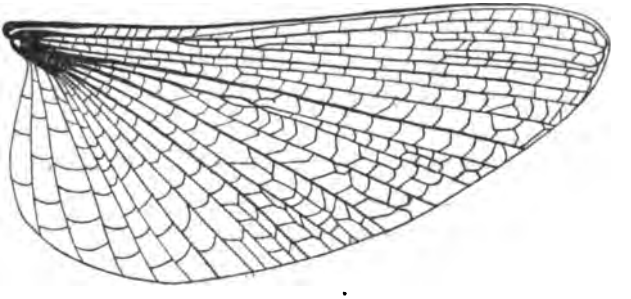


Fig. 34.—Wing of *Melanoplus bivittatus*. Original.

costal area forms the anterior edge of the wing and is bounded posteriorly by the costal vein; the *median area* is much the largest, and lies between the sub-costal and sub-median veins; the *internal area* is the free margin posterior to the internal vein. The second or lower pair of wings, (Fig. 34), are about equal to the first in length, and when the animal is at rest, are folded up under the latter. If the dark-colored marginal vein of this lower wing is gently

pulled outwards or forwards with a pair of forceps, it will be seen that it is a thin parchment-like membrane, with a stiff anterior edge, which is nearly straight, while the rounded outer and posterior margins are thin and flexible. When the wing is fully extended its upper surface is convex, and its anterior margin is rendered still more rigid by being overlapped by the internal margin of the upper wing or wing-cover. The numerous radiating veins are so arranged that their elasticity causes the wing to fold upon itself like a fan as soon as its margin is released.

THE LEGS (Fig. 35). The large leaping leg consists of five regions: The *coxa* (*c*), or basal division, which is joined to the thorax; a small articulation, the *trochanter*, (*tr*), immovably joined to the distal dorsal portion of the coxa; the *femur*, (*f*), a long, swollen, club-shaped segment, which makes up nearly half the length of the limb. When the animal is at rest it extends upwards and backwards, with its distal end above the dorsal surface of the body. This joint contains the powerful leaping muscles, the areas indicating the points of attachment being visible externally. The *tibia*, (*ti*) is about as long as the femur, but is very slender and of uniform diameter. When at rest it extends downwards and backwards, at an acute angle, from the distal end of the femur, but in the act of jumping it is thrown backwards and the limb becomes straight. The *tarsus* (*ta*), or foot, is made up of four movable pieces. The first and longest carries upon its lower surface three soft *pads* (*p*), which by their adhesion to foreign bodies serve as points of resistance in leaping. The second joint is much

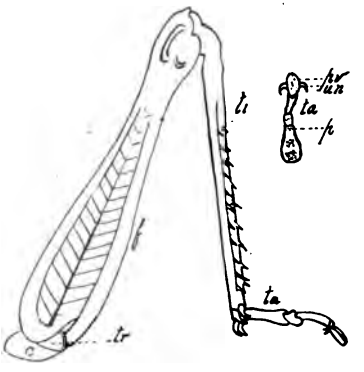


Fig. 35.—Hind leg of *Melanoplus bivittatus*. Original.

shorter and carries but one pad. The third is long and slender, with two curved, pointed claws or *ungues* (*un*), between which is a concave sucking disk, the fourth joint or *pulvillus* (*pv*). The first and second pairs of legs are much like the third, but much smaller, and they meet the body at a different angle, to fit them for crawling instead of leaping.

THE ABDOMEN.—This is made up of a number of segments without appendages, movable upon each other, and presenting only slight differences. The typical number of abdominal segments appears to be eleven, and in both sexes eleven terga are present, although only eight sterna are visible in the female and nine in the male. Fig. 36 shows a cross-section through the abdomen of a locust. The first abdominal segment is somewhat different from the others and its sternal and tergal portions are widely separate. The sternal portion is immovably united to that of the metathorax, and has been already described (*abd. st*) (Fig. 30). The tergum is soft, membranous, and dark-colored like those of the thorax, and is strongly crested in the median line. Near its lower edges are a pair of large apertures closed by membrane, the *auditory organs*, (Fig. 37, *au*), or ears. On the anterior margin of this orifice is a much smaller opening, the first abdominal *spiracle*, (Fig. 37, *sp*). The remaining abdominal segments are composed of a narrow sternal portion and a much larger tergal one. The two sides of the tergum meet along the back to form a ridge. Near the lower margin of each half of the tergum is a couple of longitudinal furrows, the traces of the sutures between the epimera and the episterna. Near the

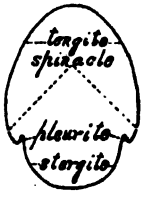


Fig. 36—Cross-section through abdomen.

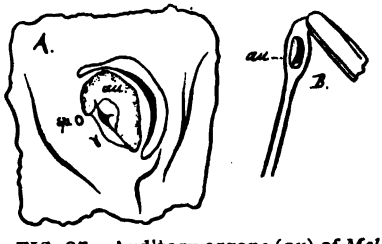


FIG. 37.—Auditory organs (*au*) of *Melanoplus bivittatus* (*A*), and of a Katydid (*B*). Original.

anterior angles of the episternal regions of the second, third, fourth, fifth, sixth, seventh and eighth segments are the openings of the spiracles, *sp*. As the structure of the terminal segments differs considerably, according to the sex of the individual, both males and females should be studied and compared. The females are usually more abundant than the males, and may be recognized by the presence of the strong, blunt, forceps-like ovipositor, which forms the posterior extremity of the body.

In the ventral view, (*C*), of the abdomen of the *male*, (Fig. 38), nine distinct movable sterna are visible; they are

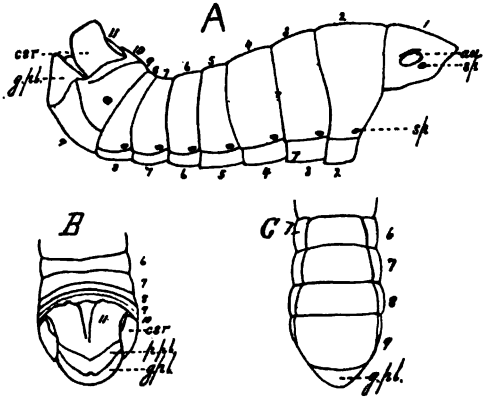


Fig. 38—Abdomen of male *Melanoplus bivittatus*. *A*, lateral view; *B*, dorsal view; *C*, ventral view. Original.

nearly equal in length and similar in shape. Posterior to the ninth sternum, the ventral surface of the body is occupied by a large spoon-shaped *sub-genital plate*, (g pl), convex below and concave above. Above this plate is a large chamber open behind, and at the sides the *genital chamber*. On the lower floor of this chamber, and therefore on the upper surface of the sub-genital plate, is the male reproductive orifice.

In a dorsal view, (*B*), the terga are substantially alike as far as the eighth. The eighth is a little shorter than the seventh. The ninth is only about one-fifth as long as the eighth, and

is immovably united to the tenth, a faintly marked suture separating the two. On the median line the tenth tergum is very narrow, but at the sides it is about as long as the ninth. The posterior margin of the tenth is sharply defined. The eleventh tergum is a movable shield-shaped plate upon the median dorsal surface. It is about as long as the eighth tergum, and it is divided into two nearly equal portions by a faint transverse suture. In shape it is quite different from the other terga, and its sides as well as its posterior margin, are free. On each side of this plate the outline of the dorsal surface of the body is completed by a setose movable plate, about as large as the eleventh tergum, the *cercus*, (*cer*). This plate projects back from the lateral margin of the tenth tergum, to which it is movably articulated. Projecting beyond the end of the eleventh tergum the end of the ventral sub-genital plate is visible. If the end of the eleventh tergum is raised, a pair of vertical plates can be seen on each side of the median line, the *podical plates*. Between these plates is the *anus*, and below them the genital chamber, already noticed.

In a side view, (*A*), the sterna of the second to eighth segments are equal in length to the corresponding terga, and the constrictions between the segments entirely surround the body. The suture, which on the dorsal surface marks the line between the ninth and tenth terga, does not extend downwards, and the lower margins of these two terga form a single plate. Below this plate is the ninth sternum, as long as the area formed by the union of the ninth and tenth terga. Running backwards from the posterior margin of the tenth tergum is the flat cercus. Above this a portion of the eleventh tergum is visible. Below and internal to the cercus is the *podical plate*, triangular in a side view, and below this the large sub-genital plate, which is joined to the ninth sternum.

The abdomen of the female, (Fig. 39), in a ventral view, (*C*), has the first to the seventh sterna like those of the male.

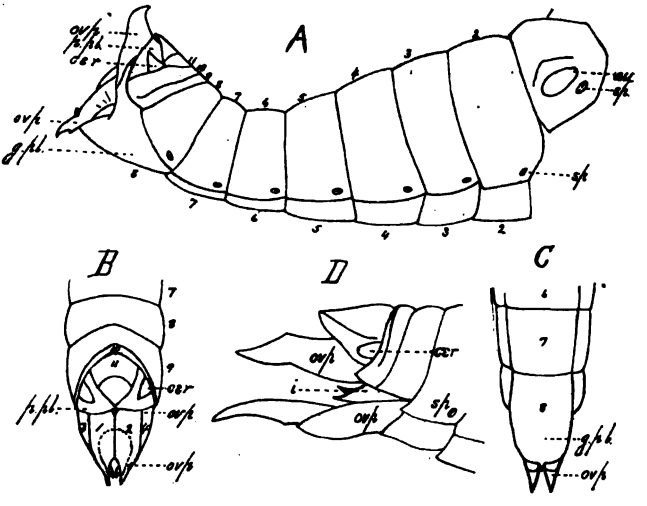


Fig. 39.—Abdomen of female of *Melanoplus bivittatus*.—*A*, lateral view; *B*, dorsal view; *C*, ventral view; *D*, egg-guide. Original.

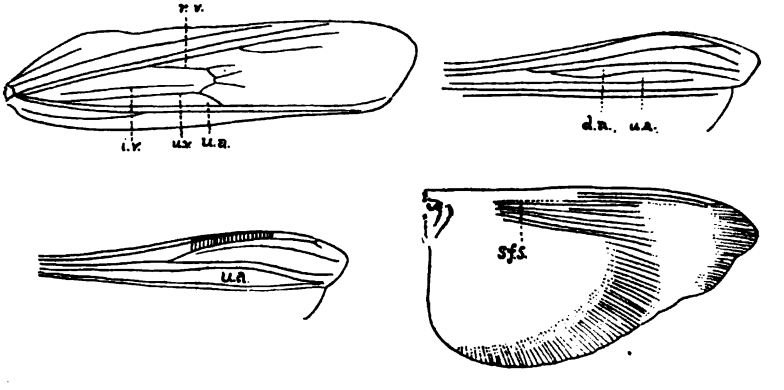
The eighth sternum is nearly twice as long as the seventh, and forms the *sub-genital plate* (*g. pl*). Its posterior end is pointed, curved upwards, and its extremity lies between the plates of the ovipositor.

In a dorsal view, (*B*), the first ten segments are substantially like those of the male. The shield-shaped eleventh tergum is shorter and wider than in the male. On each side of it, at a little lower level, is the triangular *podical plate* (*p. pl*), which is not vertical, as in the male, but is so placed that its broad surface is seen in a dorsal view. Above or dorsal to the podical plates, are the *cerci*, much smaller than in the male, but attached to the posterior margin of the tenth tergum. As in the male the *anus* is between the podical plates, just below the eleventh tergum. The space between the podical plates above and the sub-genital plate below is filled by the *ovipositor*, the top of which projects to some distance beyond the eleventh tergum.

In a side view, (*A*), the terga are substantially like those of the male, but the small cerci do not hide any portion of the

eleventh tergum, and more of the surface of the podical plate is visible than in the male, and the large genital chamber between the podical plates above and the sub-genital plate below is entirely occupied by the ovipositor.

The *ovipositor* (*ovp*), is composed of six movable pieces, three on each side of the median line; a large *superior* or dorsal piece, an equally large *inferior* or ventral piece, and a short *internal* portion between the bases of the superior and inferior pieces. In a surface view the internal portions are hidden by the two superior and two inferior pieces, which are so arranged as to form a long sheath around the internal portions which form the true ovipositor. Each of the four pieces of the sheath is pointed posteriorly, and when the pieces are folded together the four tips are in contact. Running forward from the tip is a flattened, slightly concave surface, which in the superior pieces faces backwards and upwards, and in the inferior pieces, backwards and downwards. During oviposition the four pieces are brought together and their tips forced into the ground. They are then separated, and their flattened surfaces force the earth away on all sides, making a pit into which the internal pieces then guide the egg. Fig. 39, *D*, shows the egg-guide at *i*.



Showing wings or part of wings of various species of *Œdipodinæ*.

EXPLANATIONS TO ILLUSTRATIONS OF ANATOMY OF LOCUST.

HEAD.

e—Eye.
oc—Ocellus.
epic—Epicranium.
ant—Antenna.
ant fos—Antennary fossa.
cly—Clypeus.
lbr—Labrum.
gena—Gena.
md—Mandible.
m—Mentum.
li—Ligula.
palpr—Palpiger.
lb—Labium.
lb. p—Labial palpus.
mx—Maxilla.
mx. p—Maxillary palpus.
co—Cardo.
stip—Stipes.
lac—Lacinia.
ga—Galea.
f—Foveola.
d. v—Depression of vertex.
s. v—Scutellum of vertex.

THORAX.

pro—Prothorax.
meso—Mesothorax.
meta—Metathorax.
n—Notum of prothorax (pronotum).
n'—Notum of mesothorax (mesonotum).
n''—Notum of metathorax (metanotum).
p. sc—Prescutum of pronotum.
sc—Scutum of pronotum.
scl—Scutellum of pronotum.
p.' sc' — } The same sclerites of mesonotum.
sc' — }
scl' — }
p.' scl' — }
p.'' sc'' — } The same sclerites of metanotum.
sc'' — }
scl'' — }
p.'' scl'' — }

pro. sp—Prosternal spine.
st—Sternum of prothorax.
meso. st—Sternum of mesothorax.
meta. st—Sternum of metathorax.
meso. epis—Episternum of mesothorax.
meta. epis—Episternum of metathorax.
meso, em—Epimeron of mesothorax.
meta. em—Epimeron of metathorax.
fo—Fossa.
ps—Prozona.
ms—Metazona.
h. p—Hind process of pronotum.

ABDOMEN.

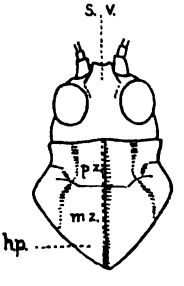
sp—Spiracle.
g. pl -Sub-genital plate.
cer—Cercus.
p. pl—Podical plates.
ovp—Ovipositor.
i—Egg-guide.

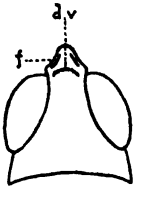
WINGS.

c. m—Costal margin.
c. v—Costal vein.
sub cv—Sub-costal vein.
m. v—Median vein.
sub m. v—Sub-median vein.
i. v—Internal vein.
D—Disk of wing.
sf. s—Subfrontal shoot.
r. v—Radial vein.
i. v—Intercalary vein.
u. v—Ulnar vein.
u. a—Ulnar area.
d. a—Discoidal area.

LEGS.

c—Coxa.
tr—Trochanter.
f—Femur.
ti—Tibia.
ta—Tarsus.
p—Pads of tarsus.
un—Ungues of tarsus.
pv—Pulvellus of tarsus.
au—Auditory organ.





INTERNAL STRUCTURE.

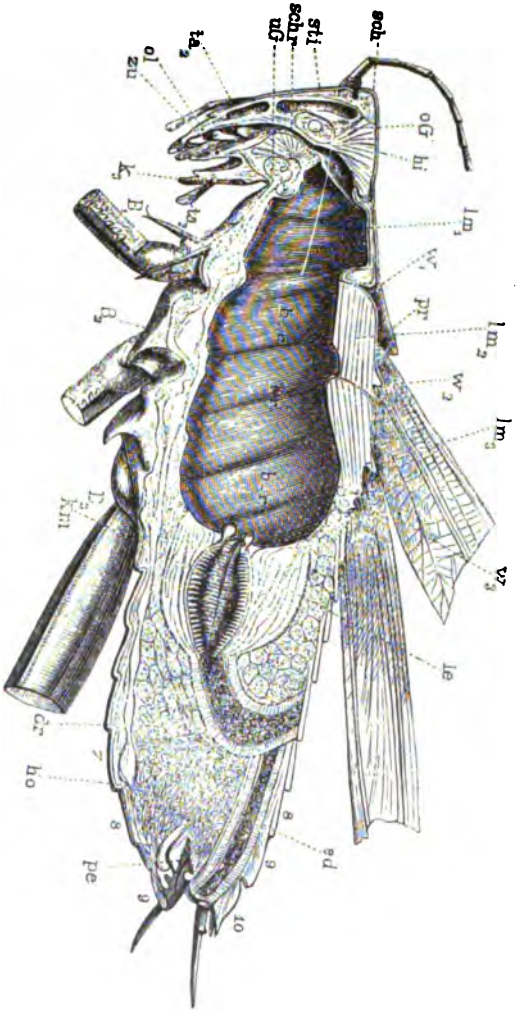


Fig. 40.—Longitudinal section through a male grasshopper (*Locusta viridissima L.*).—*hi*, occiput; *sch*, vertex; *sti*, frons. *ol*, labrum; *k 3*, labium; *zu*. ligula; *schr*, œsophagus; *kr*, crop; *km*, gizzard; *le*, caecal pouch; *ed*, colon; *og*, supra, and *ng*,sub or intra-œsophageal ganglion; *b*1, *b*2, *b*3, thoracic ganglion; *ho*, testes; *dr*, glands of the same; *pe*, penis; *lm*1, *lm*2, *lm*3, muscles of the three parts of the thorax, the latter two moving the wing-covers and wings. After Graber.

The illustration, Fig. 40, is a longitudinal section through a male grasshopper (*Locusta viridissima L.*), and shows most of the organs mentioned hereafter.

By fastening a locust, with the back uppermost under water and by cutting with a pair of fine-pointed scissors through the integument along the dorsal surface of the abdomen, the internal organs can be studied. Just below the integument on the dorsal surface of the abdomen, is seen a delicate tube, the *heart*. Just below the integument is a layer of small flat muscles, the *abdominal muscles*. By removing the dorsal integument of the thorax the *large alary muscles*, which move the wings, can be seen filling the dorsal portion of the meso- and metathorax. The muscles of the opposite sides of the body are sharply separated, and a thin chitinous partition runs down from the constriction between the meso- and metathorax, and separates the muscles of the wing-covers from those of the wings; a similar partition covers the posterior face of the wing-muscles. The space between the muscles of the abdomen and the viscera is filled with a loose network of light-colored substance, the *corpus adiposum*.

Running inward from the spiracles on the sides of the thoracic and abdominal segments are seen the tracheæ, rather tough transparent tubes, which divide into smaller branches passing to the various organs of the body. A spiral elastic fiber is coiled around the wall of each tracheal tube, which by its elasticity keeps the tube permanently open.

THE RESPIRATORY SYSTEM.—In holding a locust between our fingers we can readily observe its mode of breathing. The portion of the side of the body between the stigmata and the pleura (Fig. 36), contracts and expands, the contraction causing the spiracles to open. About 65 contractions per minute can be counted. This movement is caused by the fact that the sternal portion of the abdomen moves much more decidedly than the tergal one.

AIR SACKS.—Insects possessing great powers of flight are

especially equipped for this purpose with a large number of air sacks. Such organs are found in largest numbers in those that sail for many hours in the air, hence they are more numerous in the migratory locusts than in other members of the orthoptera or in bees and flies. By possessing such air sacks the locust can buoy itself up in the air, and as it constantly fills and refills these balloons without any great muscular exertion, it is easily borne along by favorable winds. The air sacks are intimately connected with the complicated system of air-tubes, or *tracheæ*, which ramify throughout the body; the air enters these tubes through a row of spiracles or breathing-holes (*stigmata*) located in the sides of the body. In locusts are found two pairs of thoracic and eight pairs of abdominal spiracles. The system of thoracic air-tubes, which is entirely independent of that of the abdomen, is not easily made out. The tubes arising from the two thoracic stigmata send out two well-defined tracheæ into the head, which subdivide and form the ocular air-sacks and some smaller ones in the front of the head. The five pairs of large abdominal air-sacks are derived directly from the spiracles; they can be readily seen by removing the integument from the back of the locust. There is also a large pair of air-sacks in the mesothorax, and two enormous ones in the prothorax. A number of smaller air-sacks are buried among the muscles, while others, spindle-shaped ones, occur in the end of the abdomen. As the process of respiration is much more easily performed in clear and sunny weather, we find locusts flying only at such times; in cloudy or damp weather, or after the sun sets, they are less active.

THE DIGESTIVE ORGANS.—These are quite dark in color, and vary slightly in structure according to the genus. The following description is true only of the genus *Schistocerca*. By removing the corpus adiposum, the wing-muscles and the heart, the *œsophagus* (Fig. 41, *oes*) is seen to be a tough, dark-brown, cylindrical tube, which runs up from the mouth,

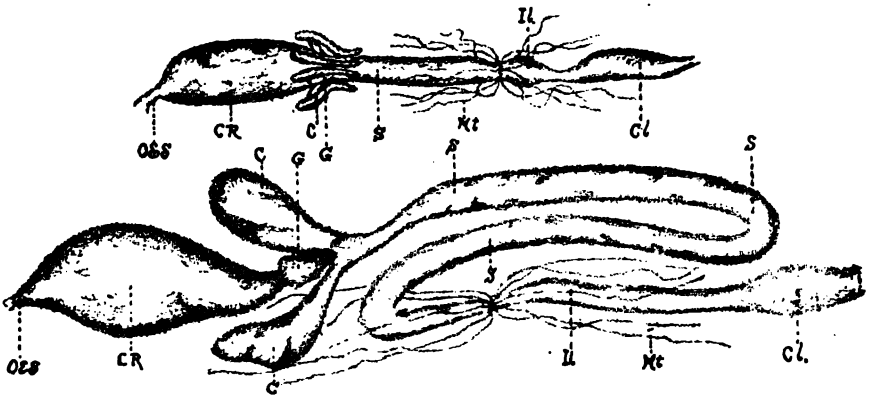


Fig. 41.—Digestive organs of a locust (above) and of a katydid or grasshopper (below). *Oes*, œsophagus; cr, crop; *g*, gizzard; *c*, cæcal pouch and tubes; *s*, stomach: *mt*, malpighian tubes; *il*, ileum; *cl*, colon. Original.

and then bends at right angles, and passes into the thorax. In the mesothorax the œsophagus gradually enlarges to form a thick-walled pouch, the crop or *ingluvies* (*cr*), which occupies the meso- and metathoracic segments. On the sides of the anterior end of the ingluvies are the delicate, white, dendritic, *salivary glands*, which communicate with two *salivary ducts*, one of which runs forward on each side of the œsophagus into the head. Running back from the posterior end of the ingluvies to the seventh abdominal segment is a large cylindrical pouch, the *proventriculus* or gizzard (*g*). Its anterior end is about as large as the posterior end of the ingluvies, and its posterior end is much smaller. Surrounding the spot, where these two chambers join each other, are sixteen transparent cone-shaped pouches, the *pyloric* or *cæcal pouches*, (*c*), placed base to base in such a way as to form a belt of eight fusiform pouches around the digestive tract. If the tracheæ, which bind them to the digestive tract, are removed it will be found that the pointed ends are free, eight of them running forewards on the sides of the ingluvies, and eight backwards on the proventriculus. Occupying the seventh, eighth and ninth abdominal segments is the *ventriculus*, or true stomach, (*s*) much smaller than the pro-

ventriculus, regularly cylindrical and abruptly constricted posteriorly, where it joins the *intestine*. Twined around the ventriculus are great numbers of small white tubes, the *malphighian tubes* (*mt*), which open into the ventriculus where it joins the proventriculus. The *ileum* (*il*), or small intestine, is a delicate, light-colored tube, which originates at the posterior end of the ventriculus, and bends abruptly upwards toward the dorsal surface, where it abruptly enlarges to form the *colon* (*cl*), a small, white, sacculated pouch, which lies directly below the terga of the ninth and tenth segments. From this a very short, narrow, *rectum* runs backward to the *anus*, which is situated between the podical plates on the lower surface of the eleventh tergum.

THE REPRODUCTIVE ORGANS.—The ovary is a long, white gland, situated above the ventriculus and proventriculus; it is made up of two sets of tubes or *ovarioles*, which are bound together into a compact mass. When this mass is carefully examined with a lens the two sets of tubes will be seen to run upwards, forwards and towards the median line. Near the posterior end of the ovary these tubes communicate with two delicate, transparent, *oviducts*, which run down around the posterior end of the ventriculus, to the ventral surface of the body. Here they unite to form a single median tube, the *vagina*, which opens externally upon the upper surface of the subgenital plate. On the median line between the internal plates of the ovipositor, there is a second much smaller external orifice, which opens into a small white pouch, the *spermatheca*, which lies above the posterior end of the vagina.

THE NERVOUS SYSTEM.—On each arch of the ingluvies is found a small, white, stellate spot, the *gastric ganglion*, radiating from which are a number of small nerves and a larger commissure, which may be traced forewards into the head, where it joins the *supra-œsophageal ganglia*, (Fig. 40, *oG*), which are situated between the eyes, in the upper surface of the œsophagus. From them a pair of short commis-

sures run down, forming a collar around the œsophagus to the ventral *nerve-chain*. This consists of commissural fibres, with the following ganglionic enlargements: A *sub-œsophageal ganglion*, (Fig. 40, *uG*), situated in the head, and sending nerves to the mouth-parts; one ganglion for each thoracic segment; four abdominal ganglia, one in the second, one in the fourth, one in the sixth, and one in the seventh segment. On each side of the nerve-chain, in the second and third thoracic and the first to seventh abdominal segments, are found *apodemata*, or projections from the sterna which support the nerve-chain.

METAMORPHOSES.

Like all other insects, the orthoptera, in growing, have to throw off their old skins and replace them with new and more commodious ones. In some orders the forms assumed after the various molts differ greatly; in butterflies, for instance, the caterpillars do not in the least resemble their parents, and the chrysalids or pupæ neither look like butterflies nor like caterpillars. All members of the order of orthoptera pass through an incomplete metamorphosis, i. e. the young insects differ but slightly from the adult ones. In the locusts the most striking differences are the absence of wings and the narrower and flattened prothorax, which is much more roof-like than in the adult. The abdomen is also quite different and more roof-shaped. The winged form is gradually assumed through a series of molts, varying from three or four to six. Species in which the wings are either entirely wanting, or that possess only rudimentary ones, generally pass through fewer molts than those having large wings when adult. The wings first appear as small wing-pads, which gradually become larger and larger, as may be seen in the illustration, (Fig. 42). As soon as the wings appear, the insect ceases to grow. There is no state of quiescence or rest in orthopterous insects as with insects that undergo a complete metamorphosis, and the

Fig. 42.—Early stages of Rocky Mountain Locust. After Riley.

nymph or pupa is as active and hungry as the imago, and differs from it only by possessing but rudimentary wings and genitalia. The latter are, however, in some cases sufficiently developed to permit coition. In cases where the species is always wingless the differences, except in size, between a newly hatched and a mature insect are sometimes very slight. Other species have in the adult stage only rudimentary wings and thus they resemble the pupal stage. It is, however, always easy to determine whether such an insect is an adult or not, as the wing-pads in the nymph are twisted in such a manner that, when closed, they are reversed and the inner surface in the imago is the outer surface in the pupa; the rudimentary lower wings are outside of the upper ones, instead of beneath. A trained eye can detect many other differences. The sexual characters are not well marked in the younger or first three stages; later the differences become apparent. Orthoptera being like all other insects enclosed in a rigid armor of a substance that will neither stretch nor grow, have to shed this skin from time to time. A locust, when ready to do so, quits feeding for a time and remains inactive during the process. In the First Annual Report of the U.S. Entomological Commission the following description is given of the last molt—from the pupa to the winged insect.

"When about to acquire wings the pupa crawls up some post, weed, grass-stalk, or other object, and clutches such object securely with the hind feet, which are drawn up under the body. In doing so the favorite position is with the head downward, though this is by no means essential. Remaining motionless in this position for several hours, with antennæ drawn down over the face, and the whole aspect betokening helplessness, the thorax, especially the wing-

pads, is noticed to swell. Presently the skin along this swollen portion splits right along the middle of the head and thorax, starting by a transverse, curved suture between the eyes, and ending at the base of the abdomen.

"Let us now imagine that we are watching one from the moment of this splitting, and when it presents the appearance of Fig. 43 *a*. As soon as the skin is split, the soft and white fore-body and head swell and gradually extrude more and more by a series of muscular contortions; the new head slowly emerges from the old skin, which, with its empty eyes, is worked back beneath, and the new feelers and legs are being drawn from their casings and the future wings from their sheaths. At the end of six or seven minutes our locust—no longer pupa and not yet imago—looks as in Fig. 43 *b*, the front four pupa-legs being generally detached and the insect hanging by the hooks of the hind feet, which were anchored while yet it had that command over them which it has now lost. The receeding skin is transparent and loosened, especially from the extremities. In six or seven minutes more of arduous labor—of swelling and contracting—with an occasional brief respite, the antennæ and the front four legs are freed, and the fulled and crimped wings extricated. The soft front legs rapidly stiffen, and, holding to its support as well as may be with these, the nascent locust employs

Fig. 43.—Molting of a locust (*Melanopolus spretus*).—*a*, nymph ready to change; *b*, the skin split along the back and the adult emerging; *c*, continues the process; and at *d*, the adult insect drying out; *e*, perfect adult. After Riley.

whatever muscular force it is capable of to draw out the end of the abdomen and its long hind legs (Fig. 43*c*). This in a few more minutes it finally does and with gait as unsteady as that of a new-dropped colt, it turns round and clambers up the side of the shrunken, cast-off skin, and there rests while the wings expand and every part of the body hardens and gains strength—the crooked wings straightening and the wings unfolding and expanding like the petals of some pale flower. The front wings are first rolled longitudinally to a point, and as they expand and unroll, the hind wings, which are tucked and gathered along the veins, at first curl over them. In ten or fifteen minutes from the time of extrication these wings are fully expanded and hang down like dampened rags. From this point on, the broad hind wings begin to fold up like fans beneath the narrower front ones, and in another ten minutes they have assumed the normal attitude of rest. Meanwhile the pale colors which always belong to the insect while molting have been gradually giving way to the natural tints, and at this stage our new-fledged locust presents an aspect fresh and bright. If now we examine the cast-off skin, we shall find every part entire with the exception of the rupture which originally took place on the back; and it would puzzle one who had not witnessed the operation to divine how the stiff hind shanks of the mature insect had been extricated from the bent skeleton left behind. They were in fact drawn over the bent knee-joint, so that during the process they were doubled throughout their length. They were as supple at the time as an oil-soaked string, and for some time after extrication they show the effects of this severe bending by their curved appearance.

"The molting, from the bursting of the pupa skin to the full adjustment of the wings and straightening of the legs of the perfect insect, occupies less than three quarters of an hour, and sometimes but half an hour. It takes place most frequently during the warmer part of the morning, and within an hour after the wings are once in position the parts have

become sufficiently dry and stiffened to enable the insect to move about with ease; and in another hour, with appetite sharpened by long fast, it joins its voracious comrades and tries its new jaws. The molting period, especially the last, is a very critical one, and during the helplessness that belongs to it the unfortunate locust falls a prey to many enemies which otherwise would not molest it, and not infrequently to the voracity of the more active individuals of its own species."

The first three skins are most frequently shed on or near the ground, under grass in little depressions, or under any other shelter that may offer. The last molts take place above the ground, as the insects like to fasten to some elevated object. The body is very soft and colorless after each molt, but soon hardens and shows the characteristic colors and markings of the species.

STRIDULATING ORGANS AND THE EAR.

Many of the orthopterous insects are musicians. Only earwigs, cockroaches, walking-sticks and praying-mantes possess no organs to produce sounds. The females of all orthopterous insects are voiceless. Such sounds do not correspond to our voice, as they are simply produced by friction. The organs by which such stridulating sounds are made are different in different families; they are very simple in some, but complex in others. The true locusts (*Acrididæ*) produce sounds by rubbing the inner surface of the hind legs against the outer surface of the wing-covers. "With these insects there is a thickening of one of the main longitudinal veins in the center of the wing-cover (*vena radialis*), and a remarkable extension of the two areas between this vein and the costal margin of the wing-cover (*area scapularis* and *area externomedia*), which serves as a sounding board and which is wanting in the female. The most common representatives of the insects which stridulate in this

way belong to the genus *Stenobothrus*." Fig. 44 shows the teeth on the inside of the femur of the hind leg, which are scraped against the veins of the tegmina. An enlarged view

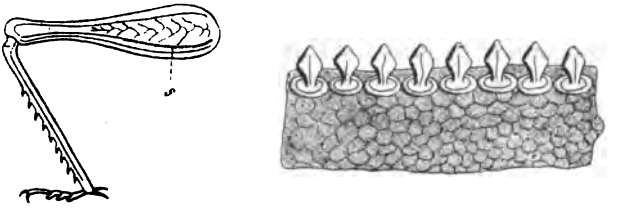


Fig. 44.—Hind leg of *Stenobothrus*; *s*, ridge with teeth. Ridge and teeth greatly enlarged. After Landois.

of these teeth is also given. According to Scudder, the *Stenobothri*, when about to stridulate, place themselves in a nearly horizontal position, with the head a little elevated; then they raise both hind legs at once, and grating the femora against the outer surface of the tegima, produce notes which in the different species vary in rapidity, number and duration. The first one or two movements are frequently noiseless or faint; and when the sky is overcast, the movements are less rapid. Prof. Scudder has recorded the songs of several species by means of a musical notation. The species of locusts that belong to the family of *Œdipodinæ* produce sounds by rubbing together the upper surface of the front edge of the wings and the under surface of the wing-covers. Such insects produce sounds only while on the wing. When we watch the common large bright-colored locust that is so abundant during the summer upon roads and sandy spots and that often remains stationary while on the wing, we can see that the wing-covers are held almost motionless in a perpendicular position, while the large and fan-like lower wings are fully expanded, and are rapidly moved up and down. The longitudinal veins of the lower wings are well developed, and as the anterior vein strikes the upper wing while flying, a rattling sound is produced. In some cases both sexes can make such sounds. Landois

has studied in detail the organs that produce sounds in insects, and some of the illustrations are copied from his paper.

The Meadow Grasshoppers, Katydids and Tree-Crickets produce sounds in a different way from the locusts. Here also the males alone can produce love songs and they alone possess peculiar organs for this purpose. The upper wings of the male are entirely different from those of the female, which have the usual form. In the male large veins divide

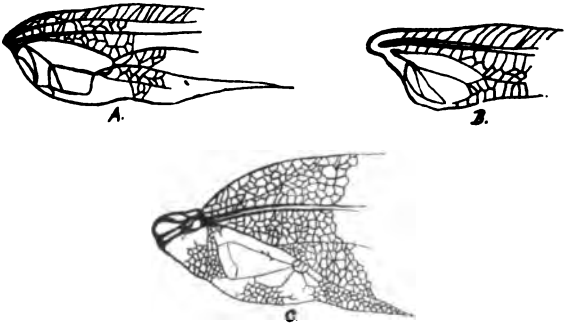


Fig. 45.—Wings of male grasshoppers.—*A*, *Orchelimum agile*; *B*, *Xiphidium fasciatum*; *C*, *Amblycorypha oblongifolia*. Original.

the wing into disk-like or drum-like spaces. Fig. 45 shows the upper wings of three species of grasshoppers, and Fig. 46

Fig. 46.—Wings of male cricket; *s*, vein with teeth; *s a*, scraper. After Landois.

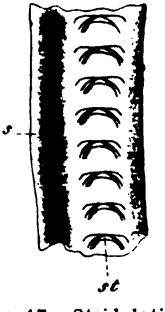


Fig. 47.—Stridulating ridges in a field cricket. After Landois.

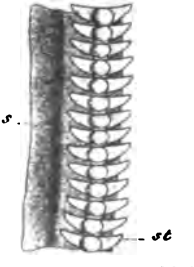


Fig. 47 A.—Stridulating ridges in a house-cricket; *s*, stridulating ridge; *st*, stridulating teeth. After Landois.

the upper wing of a cricket. The principal vein extending diagonally across the base of the wing, is furnished with

transverse ridges like a file. These ridges are also shown; their armature varies in the different species. On the inner margin of the wing is a hardened and elevated space or scraper, hence each upper wing is provided with a file and a scraper, the latter covered with short and stiff bristles. Fig. 48 shows the scraper at s, and the

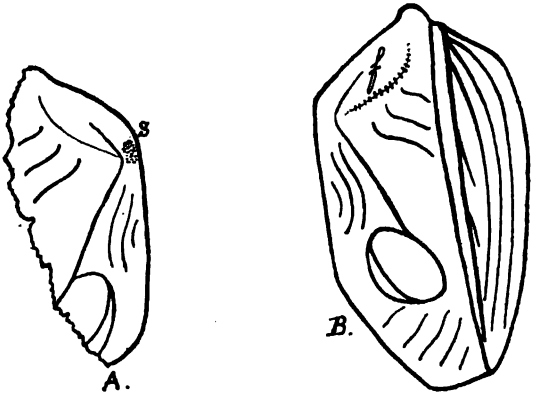


Fig. 48.—Stridulating organs (file and scraper) of *Gryllus abbreviatus*. A, dorsal surface; s, scraper formed of bristles; B, ventral surface; f, file. Original.

files at f. By elevating the upper wing at an angle of about forty-five degrees with the body, the scraper of one wing rests on the file of the other, and by moving the wings they rasp on each other. The sound is strengthened by the vibrating wings, which act as sounding-boards. The illustrations (Fig. 48) show the organs greatly enlarged. If insects produce sounds they must be able to hear them, otherwise the male locusts, grasshoppers and crickets would sing in vain, and we find in many cases in both sexes of those insects, organs that have most probably a function very similar to that of our ears; but we must not look for such organs where we are apt to expect them to be. The locusts have their ears on the first joint of the abdomen (Fig. 37), while the grasshoppers and crickets have them near the upper part of the front tibiæ (Fig. 37 and 174, *c-f*). All three families of stridulating orthoptera raise the

wings at the time of producing sound by vibrating them, in fact almost the whole body vibrates—is a sort of sounding-board. Both actions strengthen the sounds. We can do the same thing if we vibrate the strings of a guitar and swing the instrument in the air; in this manner we imitate the sounds of bells, in other words, increase the sounds. It is also a well known fact that the pitch of a sound depends upon the number of vibrations. Knowing the number of vibrations we can judge from the sounds how many were made to produce them. If, for instance, a fly produces during flight the sound f′, it had to make 352 beats of the wings per second to do so. If our honey-bee is active the sound a′ is produced during flight, or 440 beats per second; if tired e′ is produced, or 336 beats per second.

Some insects also produce sounds to communicate with others of their kind. If we put some honey near the entrance of a bee-hive some of the bees will soon discover it, and they immediately call others to this valuable Klondyke of honey by producing the sounds a″, h″, or c‴, according to their size. These sounds will invariably call many bees from the hive, and the honey is soon stored away in safer quarters.

ORTHOPTERA OF MINNESOTA.

The members of this order are, almost without exception, injurious to agriculture, horticulture and forestry, and some of them have become a very annoying pest in our houses. When we listen during the warm nights of summer to the songs of our arboreal Katydids, to the chirping sounds of crickets, or to the shriller tones produced by locusts and grasshoppers, we are apt to forget that insects forming this order of insects belong to the most terrible scourges known to man. The older inhabitants of our state are not apt to forget, however, the devastations caused by the great swarms of migratory locusts in the past, while more recently farmers in various parts of the state had to

complain more than once about the losses inflicted by such insects.

With the exception of a single family of Orthoptera, the Praying Mantes, Rear-horses or Soothsayers (*Mantidæ*), all the insects forming this order are more or less injurious to vegetation, and as insects of the above family are not found in our state it may be stated that all are injurious, and that all demand the careful attention of the practical farmer and of the student of agriculture and allied pursuits.

CHARACTERS OF THE ORDER ORTHOPTERA.

The Orthoptera form a very compact and natural order if we omit the small family of Earwigs (*Forficulidæ*), as has been done by many writers, and the characters of the members of this order may be briefly stated as follows: They possess four wings, of which the first or upper pair are thick, leathery or parchment-like, overlapping while at rest, and forming protecting covers for the much more delicate second or lower pair of wings, which are thinner and folded longitudinally like a fan. The fore-wings or tegmina are not used in flight, the hind wings are the true organs for this purpose. Not all Orthoptera possess well developed wings, and there are some wingless genera and species in this order; in some cases the anterior wings are only rudimentary or wanting. The mouth-parts are formed for biting and chewing food. The metamorphosis is incomplete, i. e. insects belonging to this order have no period of inactivity from the moment they are hatched to their adult state, and the young insect always resembles the adult one or imago except in size and the absence of wings and perfect sexual organs.

The name Orthoptera is derived from two Greek words, i. e. *orthos*—straight, and *pteron*—a wing.

CLASSIFICATION OF ORTHOPTERA.

Prof. Comstock* divides this order into seven families, which are grouped in five sections. Each of the first four sections contain but a single family, the fifth one includes the three remaining ones. The names of the sections, with the exception of the first one, were suggested by the form of the legs. The following are the names of the sections and of the families they include:

I. *Dermaptera;* includes the *Forficulidae* or EARWIGS.

II. *Cursoria* or Runners; includes the *Blattidæ* or COCKROACHES.

III. *Raptatoria* or Graspers; includes the *Mantidæ* or REAR-HORSES.

IV. *Ambulatoria* or Walkers; includes the *Phasmidæ* or WALKING-STICKS.

V. *Saltatoria* or Jumpers; includes the *Acrididæ* or LOCUSTS or SHORT-HORNED GRASSHOPPERS, the *Locustidæ* or LONG-HORNED GRASSHOPPERS and KATYDIDS, and the *Gryllidæ* or CRICKETS.

Prof. Scudder,** our highest authority on this order of insects, whether recent or fossil, also arranges them in the above seven families.

With the exception of the Rear-horses (*Mantidæ*) all the families are represented by one or many species.

To enable the student to recognize the different families, the following table is quoted from Prof. Comstock's Introduction:

TABLE OF FAMILIES OF ORTHOPTERA.

A. Posterior femora fitted for walking, i. e. resembling those of the other legs; ovipositor with the subgenital plate concealed; organs of flight of immature forms in normal position; insects mute.

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*An Introduction to Entomology, by John Henry Comstock, 1888.

**Guide to the Genera and Classification of the N. A. Orthoptera, by Samuel Hubbard Scudder, 1897.

B. Anterior wings leathery, very short, without veins, meeting in a straight line; posterior wings, when present, folded to the middle of the anterior margin; tarsi three-jointed, the pulvillus wanting; cerci horny, resembling forceps. 1. *Forficulidæ.*

BB. Anterior wings parchment-like, thickly veined; posterior wings folded to the base; tarsi five-jointed; cerci soft, jointed or without joints.

C. Body oval, depressed; head wholly or almost wholly withdrawn beneath the pronotum; pronotum shield-like, transverse; legs compressed; cerci jointed; rapidly running insects. 2. *Blattidæ.*

CC. Body elongated; head free; pronotum elongated; legs slender, rounded; cerci jointed or without joints; walking insects.

D. Front legs fitted for grasping; cerci jointed. 3. *Mantidæ.*

DD. Front legs simple; cerci without joints. 4. *Phasmidæ.*

AA. Posterior femora fitted for jumping, i. e. very much stouter or very much longer, or both stouter and longer that the middle femora; ovipositor horny, free (except with the Mole crickets); organs of flight of immature forms inverted; stridulating insects.

B. Antennæ short; tarsi three-jointed; supposed organs of hearing situated in the first abdominal segment; ovipositor short, composed of four separate plates; stridulating organs situated in hind femora and the costal area of the tegmina. 5. *Acrididæ.*

BB. Antennæ long, setaceous; tarsi four or three-jointed; supposed organs of hearing situated in the anterior tibiæ and also in the prosternum; ovipositor elongated (except in the Mole crickets); composed of four connate plates.

C. Tarsi four-jointed; ovipositor (when exerted) forming a strongly compressed, generally sword-shaped blade; the stridulating organs of male limited to the anal area of the tegmina.
6. *Locustidæ.*

CC. Tarsi three-jointed; ovipositor (when exerted) forming a nearly cylindrical, straight, or occasionally up-curved needle; the stridulating organs of the male extend across the anal and median areas of the tegmina.
7. *Gryllidæ.*

Prof. Fernald* gives a very handy short table to separate the New England Orthoptera into families, in which each figure on the right leads to the same one on the left:

1 { Hind legs longest; hind femora thickened; (jumpers)..4
  { Legs of nearly equal length; hind femora not thickened (runners).....2

2 { Abdomen with forceps-like appendage at the end..... *Forficulidæ.*
  { Abdomen without forceps at the end.....3

3 { Body oval and flattened.....*Blattidæ.*
  { Body long and slender.....*Phasmidæ.*

4 { Antennæ shorter than the body.....*Acrididæ.*
  { Antennæ longer than the body.....5

5 { Wing-covers flat above, but bent sharply down at the sides.....*Gryllidæ.*
  { Wing-covers sloping down on the sides.. .....*Locustidæ.*

FAMILY I.

EARWIGS.

(*Forficulidæ*).

These insects resemble beetles, and are so different from true orthoptera that many entomologists consider them as members of a different order, the *Dermaptera* or *Euplexoptera*.

They possess very small and leathery wing-covers or

*The Orthoptera of New England, by C. H. Fernald, A. M., Ph. D., 1888.

tegmina, without veins, which meet, as in beetles, in a straight line down the back; they cover partially the lower wings, which are furnished with a peculiar network of veins, as may be seen in the illustration (Fig. 49). These lower wings are large when extended, and present a beautiful appearance with their numerous radiating veins, which in closing the wing act as the bars of a fan. When snugly hidden away under the small upper wing it is difficult to understand how such a large object can be folded up into such a small space. This is done by first folding the wing longitudinally, and a second time transversely. It is very amusing to watch an earwig folding or unfolding these wings, as it needs for this purpose the assistance of the horny cerci resembling forceps. The tarsi are composed of three joints, and no pulvilli are found between the claws.

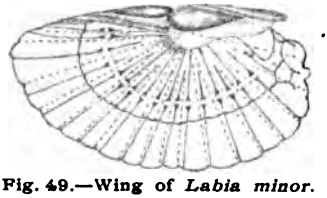


Fig. 49.—Wing of *Labia minor.*

But two species are found in Minnesota, where these insects are rare. Earwigs are nocturnal in their habits, hiding during the day among all sorts of litter and in cracks and crevices. Sometimes they are attracted into houses by bright light. In Europe such insects are very abundant and prove sometimes injurious, especially to ripe fruit and to flowers in greenhouses. They are strictly vegetable feeders and are very fond of such sweet material as ripe fruit and the corollas of flowers, etc. When abundant they are caught below flower-pots and in other hollow objects, as the stems of sun-flowers, into which they crawl to hide during the day. Some people are very much afraid of such little insects; they believe that they will enter the ears and cause them all sorts of serious trouble. Of course such notions are nonsensical, and the insect, notwithstanding its formidable appearance, lacks the power of doing such harm; it may simply enter an ear as the first dark shelter that offers, if it is dislodged from its hiding place.

The female earwig lays a cluster of small, oval, yellowish and opaque eggs under a fallen leaf or under any other shaded object, and then nestles upon it as a hen on her eggs; she also protects the young for sometime after being hatched.

In the tropics large numbers of such insects are found; some of them are brightly colored, and decidedly ferocious in appearance, especially the males, which possess formidable looking forceps, those of the female being usually smaller and more simple.

Two genera, each represented by one species, occur in our state.*

GENUS *Labia* Leach.

Body small and convex; head moderately large; antennæ composed of from 10 to 15 joints, the sixth joint being plainly obconic. Pronotum somewhat smaller than the head; wing-covers always present, though the wings are sometimes wanting. Abdomen somewhat widened in the middle; the last segment much longer than the others, and armed with a pair of forceps, separated at the base in the males, but not separated in the females. Legs comparatively short; the first joint of the tarsi as long as the other two, the simple and compressed second one is the shortest.

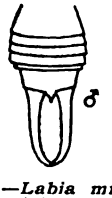


Fig. 50.—*Labia minor.* Original.

THE LITTLE EARWIG.

(*Labia minor* Linn.).

Head and sides of abdomen nearly black; mouth-parts, antennæ, thorax, wing-covers, exposed parts of the lower wings, and the middle of the upper side

*In studying the structure of the single and mutilated specimen of a second genus, the former was destroyed, hence only one genus could be described and illustrated. More material is needed for this purpose.

of the abdomen, yellowish-brown; the last segment of the abdomen and the forceps, reddish-brown. Legs and last two joints of the antennæ honey-yellow. The entire surface of the body is covered with fine and short hairs. The illustration, (Fig. 30), shows this insect greatly enlarged; the natural size is also given.

The only specimens collected in Minnesota were attracted to light, but as most of our windows are fitted with wire screens to exclude insects, earwigs may be more common than they appear to be. While tenting in July large numbers of this species were seen, attracted to the camp-fires, but none were secured at the time.

FAMILY II.

COCKROACHES.

(*Blattidæ**).

These well-known insects possess an oval and usually very much depressed body, with the nearly horizontal head almost entirely withdrawn below the shield-like pronotum; the head is bent down in such a manner that the powerful mouth-parts, with their strong and biting jaws, project backwards between the bases of the first pair of legs. Besides the large eyes there are usually two rudimentary ocelli. The antennæ are very long and slender, often having upwards of hundred joints; the legs are long, armed with numerous bristles.

Cockroaches are by no means uncommon in our state, and some species, which are frequently called "Croton bugs" and "Black beetles," are well known household pests. Other species are found under rubbish, loose bark, about ant-hills, and, though common, are not often seen, as all cockroaches are more or less nocturnal insects. Some of the native species are attracted to light, others to sweetish fluids left out of doors. Cockroaches are general feeders, and the domestic species injure all kinds of provisions; they also

*Blatta, a cockroach.

quite often spoil the covers of books by eating the size or paste used in bindings. Glue under postage stamps and similar things is frequently eaten by them. In more southern regions they become much more destructive. Blackened boots are ruined by them over night, as they devour the upper surface of the leather to obtain the molasses used in making blacking; they also gnaw off the upper surface of toe-nails of sleeping persons and even remove the eye-lashes of sleeping infants.

They are very fond of damp and warm situations, hence those invading our houses are most numerous in kitchens and especially in the vicinity of steam and water pipes. Their peculiar flat shape enables them to enter even very narrow cracks, and on that account we find them sometimes very numerous below the baseboards in kitchens, or in the drawers of tables, etc. Whenever they occur in numbers their disgusting, fetid odor reveals their presence, and rooms inhabited by them can be recognized by this odor, which is very difficult to remove. In pantries crowded with these insects the dishes will possess this odor even after having been washed. But notwithstanding all these bad qualities they possess one redeeming character; they are said to devour bed-bugs.

Most cockroaches deposit their eggs in a purse-like pod called an *Ootheca* (Fig. 51). This pod varies in the different genera in shape and size, but is usually more or less bean-shaped. It is divided into two rows of cells, each cell enclosing one egg, and possesses at the upper ridge a longitudinal slit, through which the young insects escape, frequently assisted by their mother. Such a brownish bean-like pod is frequently seen protruding from the end of the abdomen of a female, the latter carrying it until the eggs are ready to hatch. In some

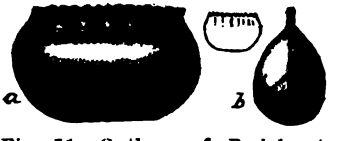


Fig. 51.—Ootheca of *Periplaneta orientalis*; *a*, side; *b*, end view. Natural size indicated by outline figure. From "Household Insects," published by U. S. Div. of Entomology.

cases living young are produced, but none of our native species have this habit. All young cockroaches resemble their parents in form, but are wholly wingless, the wings not appearing until after the fifth or last molt.

To the paleontologist, interested in tracing back the ancestry of insects, the *Blattidæ* are a group of surpassing interest, as the oldest known insect is a cockroach described from the Middle Silurian of France. About eighty fossil species of this family are known. Prof. S. H. Scudder, our eminent authority on fossil and recent orthoptera, says of the cockroach: "Of no other type of insects can it be said that it occurs at every horizon where insects have been found in any numbers; in no group whatever can the changes wrought by time be so carefully and completely studied as here; none other has furnished more important evidence concerning the phylogeny of insects."

SYNOPSIS OF THE GENERA.

Prof. Fernald gives the following synopsis:

1 { Sub-anal styles wanting in the males; last joint of the abdomen of the female not divided.....*Blatta*.
  { Sub-anal styles present in the males; last joint of the abdomen of the female divided.....2

2 { Supra-anal plate fissured.....*Periplaneta*.
  { Supra-anal plate not fissured.....*Platamodes*.

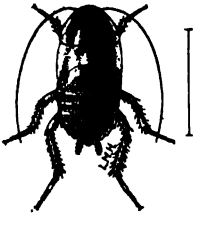


Fig. 52. — Unwinged Cockroach. Original.

Prof. Scudder, in his "Guide to Orthoptera," has divided this order into seven sub-families, two of which are found in our state, the *Blattinæ* containing the genera *Ischnoptera* (*Platomodes*) and *Blatta*, and the *Periplanetinæ*, the genus *Periplaneta*. A number of unwinged species of cockroaches occur in Minnesota under loose bark, but have not bee n studied. They are more or less active during warm days in winter, and not easily captured even then. One is shown in Fig. 52.

GENUS *Blatta*, Linn.

Insects belonging here possess a pad (*pulvillus*) between the claws of the feet; the seventh sternum of the abdomen is entire in both sexes; the sub-anal styles are rudimentary in the males.

THE CROTON BUG.

(*Blatta germanica* Fab.).

Few insects are better known than this household pest, which now occurs almost everywhere, not alone in the larger cities but in the smaller ones as well. Originally from the orient it found a home long ago in Europe, and has since spread to all civilized regions of the globe. As nearly all vessels, and especially steamers, offer numerous shelters near steam and water pipes, these insects can readily spread from port to port. The name "Croton bug" originated in the City of New York, and was suggested by the fact that the insects became very numerous in houses containing water pipes connected with the Croton aqueduct.

The insects are light brown or dull yellowish, with a yellowish brown head and long yellowish antennæ; the pronotum is marked with two longitudinal black stripes. The wing-covers and wings extend beyond the tip of the abdomen.

About 36 eggs are enclosed in a capsule, which is carried about for a long lime by the mother. It is stated that when the young cockroaches hatch, the mother assists them to escape from the oötheca. The young insects are perfectly white at first, but soon acquire their normal color. They have to shed their skins six times before they reach their full size, which takes from four to five months. After each mo t the still soft insects are white, and are frequently called "Albino roaches." Although nocturnal in their habits they do not avoid the daylight as much as other species of cockroaches, and may frequently be seen moving about during

the day. These insects feed on almost everything, but seem to prefer wheat bread; they also delight to "sleep and board" among crackers, and these suffer severely during a long trip on board of a vessel. Libraries are often crowded with these insects, which find good shelters among the books, and here they cause sometimes much damage by gnawing the bindings of books bound in cloth. As most people living in houses frequented by these insects know them thoroughly well it is not necessary to give their life history in detail. This insect is much more active and wary than the larger kinds, and on that account more difficult to eradicate.

The insect illustrated in all stages in Fig. 53, measures from 11 to 13 mm. in length.

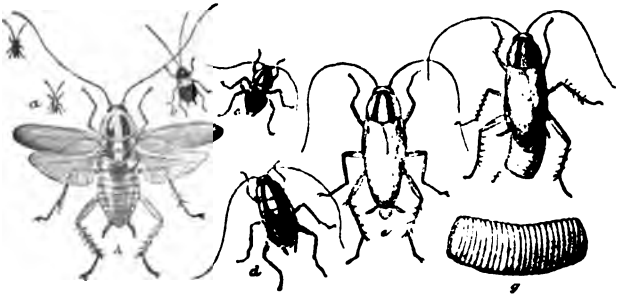


Fig. 53.—*Blatta germanica; a*, first stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, adult; *f*, adult female with egg-case; *g*, egg-case enlarged; *h*, adult with wings spread. All natural size except *g*. From "Household Insects," published by U. S. States Div. of Entomology.

GENUS *Periplaneta* Burmeister.

Last abdominal sternum of the female divided; sub-anal styles of the males well developed. Antennæ slim and tapering, longer than the body. Legs long and very spiny.

Wing-covers and wings extending beyond the end of the abdomen in both sexes.....*americana*.

Wing-covers and wings not reaching to the end of the abdomen in the males, rudimentary in the females..*orientalis*.

THE ORIENTAL COCKROACH OR BLACK BEETLE.

(*Periplaneta orientalis* Fab.)

This large insect is also a cosmopolite, inhabiting dwellings throughout the civilized world. It is a very dark brown, almost black and shining insect, with no bands or markings on the pronotum. Legs lighter in color than the body. In the male both wing-covers and wings are well developed, but do not quite reach the end of the abdomen; in the female the tegmina are very small, not more than one-fifth of an inch long, and no true wings are found beneath them. The illustration, (Fig. 54), shows this insect.

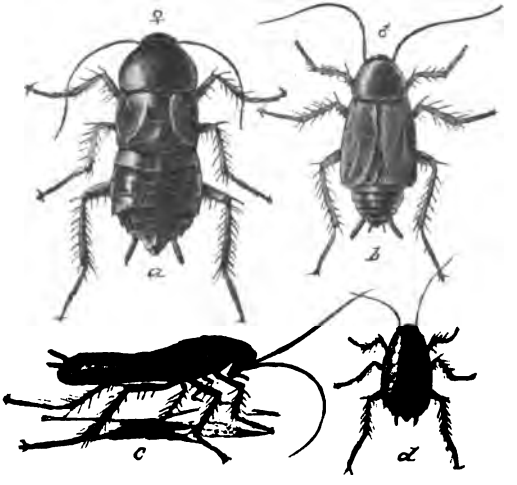


Fig. 54.—*Periplaneta orientalis; a*, female; *b*, male; *c*, side view of female; *d*, half-grown specimen. All natural sizes. From "Household Insects," published by U. S. Division of Entomology.

This species is very gregarious in habit, and many individuals, large and small, live together in colonies on the most friendly terms. The female deposits 16 eggs in two rows in a large and horny brown capsule, (Fig. 51), which is carried about for some time and is then dropped into a safe and warm place. The young roaches escape without assistance, and to enable them to do so they discharge a fluid that

softens the cement along the suture of the egg-capsule. The young, at first white, are very active, and feed, like their parents, upon any starchy food they can obtain. Flour, bread, meat, cheese, fruit, woolen clothes, even old leather, are not despised. The species is very shy, and is never seen during the day. It can become very destructive in stores and bakeries, where it defiles as much as it devours, and where its fetid odor becomes far from appetizing.

In Minnesota it is not found in large numbers. It seems as if the cold of our winters, which is sometimes rather severe, killed a large number of them every year, and thus kept it in check. Length, 20 to 23 mm.

THE AMERICAN COCKROACH.

(*Periplaneta americana* Fab.).

This is a native species, originating in tropical or subtropical America. It is illustrated in Fig. 55. It is reddish-

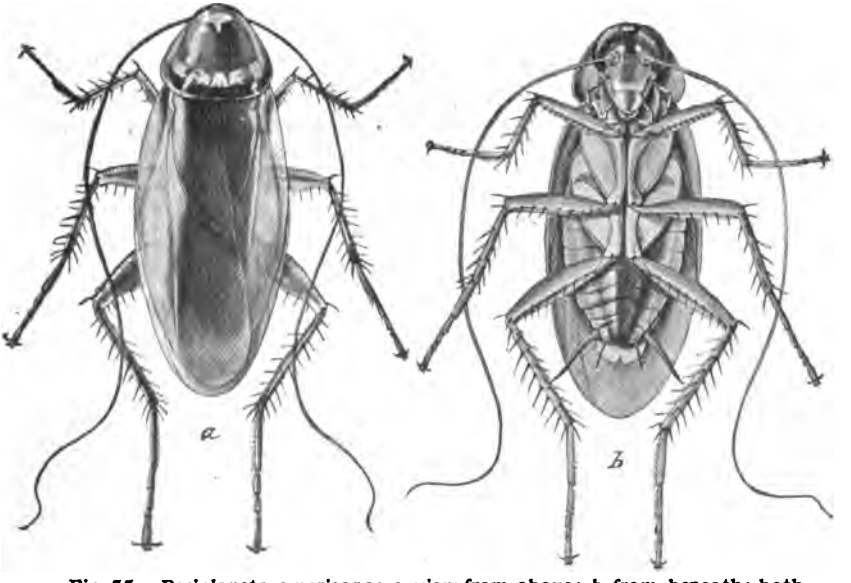


Fig. 55.—*Periplaneta americana; a*, view from above; *b*, from beneath; both enlarged one-third. From "Household Insects," published by U. S. Div. of Entomology.

brown, with paler and indistinct bands on the pronotum. The wings are unusually long, and both wing-covers and wings are well developed in both sexes, extending beyond the tip of the abdomen. The legs are much lighter in color than the body.

It is not often found in our houses, and only in larger cities. It seem that very severe cold will kill it, hence it is from time to time exterminated. It occurs most frequently in stores where bananas are kept and sold, and it is very likely that it is re-introduced every year with this fruit which also harbors many other things. [It will surprise the reader to hear that the following natural-history objects have been found hidden in banana bunches in the city of Minneapolis: a young snake (*Boa constrictor*), 14 inches long; a large crab, four inches across the back; two species of scorpions; several large thousand-legs (*Scolopendra*); some large and black cockroaches; several large and hairy bird-spiders, usually called tarantula, and many other smaller insects and other beings.]

The American cockroach is sometimes very injurious in greenhouses, where it destroys tender plants. Being found in large numbers on vessels it has found a home in many seaport towns in foreign countries.

THE AUSTRALIAN COCKROACH,

(*Periplaneta australasiæ*),

resembles the American species very closely, but possesses a brighter and more clearly defined yellow band on the prothorax, and a yellow dash on the upper wings. Though more troublesome in the south it has also found a home in more northern regions, and is fast becoming a cosmopolitan. It may occur here from time to time, being introduced with goods from southern cities. This species is shown in Fig. 56.

As already mentioned, not infrequently foreign species of cockroaches are found hiding in bunches of bananas. As

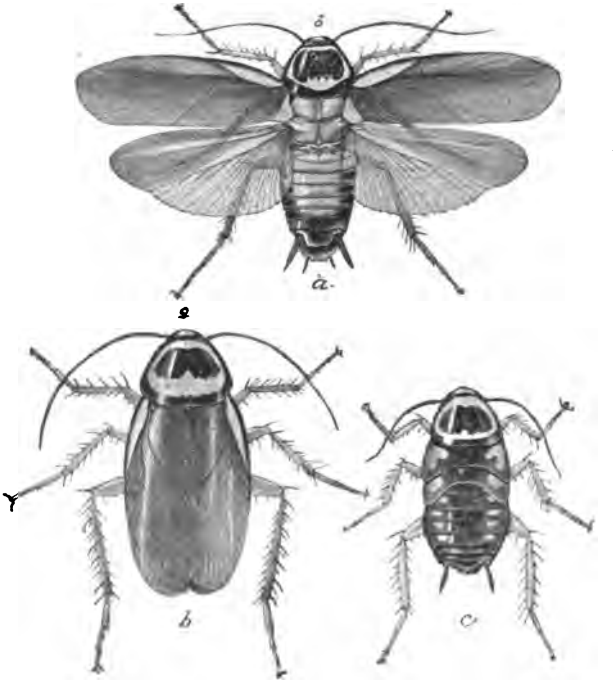


Fig. 56.—*Periplaneta australasiæ*; *a*, male with spread wings *b*, female; *c*, pupa—all life size. From "Household Insects," published by U. S. Div. of Entomology.

a general rule they can not exist here and soon perish. The pupa of one species, *Nyctobora holosericea*, Burm., is shown in the illustration (Fig. 57).

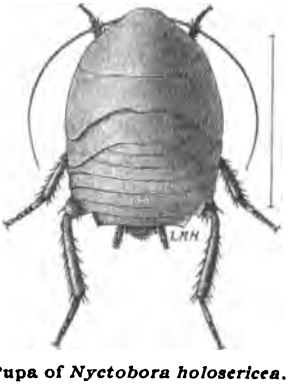


Fig. 57.—Pupa of *Nyctobora holosericea*. Original.

GENUS *Ischnoptera*.

(*Platamodes* Scudder).

A genus more closely allied to *Periplaneta* than to any other, but readily distinguishable from it by its much narrower and more elongated body, the sides being sub-parallel throughout their whole extent, while in *Periplaneta* the abdomen is much swollen. The wings and wing-covers extend beyond the abdomen, the latter being well rounded at the tip. The supra-anal plate is regularly rounded, but lacks altogether the fissuration seen in *Periplaneta*. The anal cerci are somewhat shorter and not so flattened as in *Periplaneta*, while the anal styles are very short, and turned abruptly downwards. In *Periplaneta* the sub-genital plate does not extend as far backward as the supra-anal. In *Ischnoptera* it extends backward farther. A further distinction between the two genera may be seen at the inner border of the eyes, which in *Ischnoptera* are nearly parallel, while in *Periplaneta* they approach one another anteriorly.

THE COMMON WOOD-COCKROACH.

(*Ischnoptera pennsylvanica* De G.).

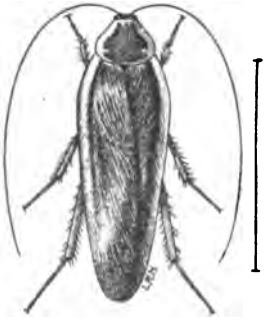


Fig. 58.—*Ischnoptera pennsylvanica*. Original.

This species, (Fig. 58), has long and delicate, light-colored wing-covers and wings which extend considerably beyond the tip of the abdomen. The margin of the pronotum is light, while the disk is dark; the lateral margins of the tegmina, especially at the base, are lighter than the discal portions.

It is a native of our woods, and is frequently found in July in our houses, being readily attracted to light. Entomologists in the habit of "sugaring" for moths not infrequently find these roaches enjoying this sweet food. Length 25 mm. or more.

THE UNIFORM WOOD-COCKROACH.

(*Ischnoptera unicolor* Scud.).

Wings and wing-covers of a uniform, pale, shining, reddish-brown; color head and pronotum slightly darker, especially in the middle; abdomen darker above, especially on the borders; cerci dark brown; legs, especially the tibiæ, darker than the body; eyes black; antennæ and palpi brown; antennæ reaching backwards to the tip of wing-covers. (Fig. 59).

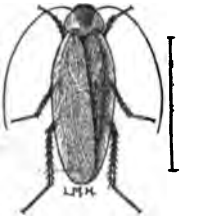


Fig. 59.—*Ischnoptera unicolor.* Original.

These insects are not common, but are found occasionally late in June below loose bark in our forests.

THE NORTHERN WOOD-COCKROACH.

(*Ischnoptera borealis* Linn.).

It may also occur in our state, though no undoubted specimens have been found.

The family of cockroaches has not yet received the attention of entomologists and collectors, hence the species composing it are not as numerous as they will be in the future, when every part of our state has been thoroughly explored.

FAMILY III.

REAR-HORSES. PRAYING MANTIS.*

(*Mantidæ*).

The peculiar insects forming this family are chiefly inhabitants of tropical countries, and but few species occur in the United States, and none in Minnesota. They are found, however, south of us not much beyond the northern part of Missouri. Wherever it occurs it attracts the attention of all observers, and even those not interested in such matters are apt to notice this grotesque insect, which assumes,

*Mantis, a prophet; also Greek name for such insects

when waiting for a victim, the position of prayer, as seen in the illustration, (Fig. 60). This peculiar position, as well

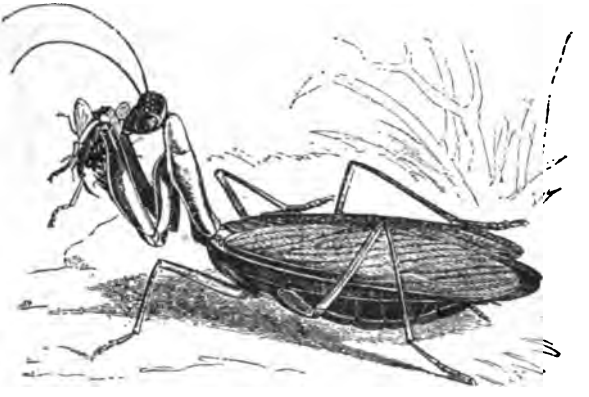


Fig. 60.—Praying Mantis.

as its strange motion of swaying to and fro the elongated front part of the body, and of assuming other strange attitudes, has procured it many popular names, some of which as peculiar as the insect itself. Rear-horse, Race-horse, Camel-cricket, Praying-mantis, Soothsayer, etc., are a few of them.

The elongated prothorax, which is the longest segment of the body, the enlarged front legs fitted for grasping, and in which the coxæ are very greatly enlarged, the large and movable head loosely joined to a neck, are the most striking characters of this large insect. The wing-covers are brown or green, according to the sex, and are frequently highly colored and marked. The sexes differ considerably, the male being slender with long wings, while the female has only shorter ones, which can hardly be used for flight. As the insect is not a native of our state it is not necessary to give an extended description of it; the illustration is sufficient to show its essential features.

All the species of *Mantidæ* are carnivorous, but they do not pursue their prey as is usually the habit of such insects; they depend on their resemblance to twigs, leaves, etc., and

wait patiently for insects to come near, when they suddenly change their praying position to a preying one, and seize their unsuspecting victim with their terrible arms.

The eggs, which are laid in peculiar clusters on twigs and fences, are also encased in flattened oötheca, differing from those of the cockroaches by being composed of hardened silky matter. The ridiculous looking young insects are cannibals, and the old ones are the worst fighters on record, beating even the celebrated Kilkenny cats.

FAMILY IV.

WALKING-STICKS.

(*Phasmidæ**).

This family is also best represented in the tropics, where numerous species occur. Most of them possess very strange forms; some resemble fresh and green leaves, others look tke old and withered ones, and still others resemble twigs very closely. The famous "Walking-leaf" is an insect that belongs to this family. On account of these peculiar shapes, insects of this kind are not readily seen, and thus escape their enemies among the feathered tribe. All are strictly vegetable feeders, hence can become injurious when found in large numbers upon useful plants. Several species occur in the United States, and one, which is illustrated in Fig. 61, is found in Minnesota.

Our American insects are spectre-like beings, possessing a linear body furnished with long legs and antennæ. Yet notwithstanding their long legs they are exceedingly slow in all their motions, and remain for a long time stationary.

Unlike other orthoptera mentioned thus far, their large and oval eggs are laid singly, not united with others in a capsule.

GENUS *Diapheromera* Gray.

Body long, slender and cylindrical. Head oval and slightly inclined. Antennæ long, slender, and composed of

*Phasma, a spectre.

numerous joints, inserted in front of the eyes. Palpi short, cylindrical. Legs simple, the anterior pair similar to the others. Tarsi five-jointed. Elytra very short, or wanting.

THE COMMON WALKING-STICK.

(*Diapheromera femorata Say*).

This is a very common insect in Minnesota, yet very few persons have ever seen it, and if it is shown to them they are greatly astonished to hear that it may be found in large numbers during the autumn by beating bushes, especially of hazel and oak, over an inverted umbrella. The insect, (Fig. 61), is either greenish or greenish-brown. These colors vary, however, very greatly, the green color being dominant early in the season, while the brown color is more common later. The head of the male usually shows three brown stripes; that of the female two, one on each side, extending backwards from the base of the antennæ. With the exception of the anterior pair of legs the femora of all others are armed on the under side with stout and acute spines. The tibiæ of the anterior legs of the male are green in most specimens found in Minnesota; the femora of the middle pair of legs are marked with darker bands. Elytra entirely wanting.

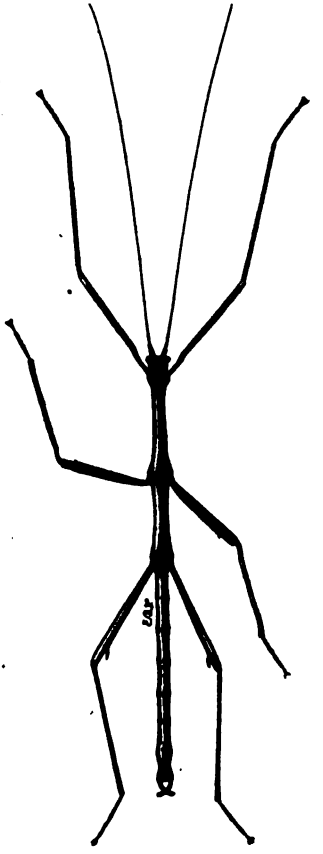


Fig. 61.—*Diapheromera femorata.* Original.

The black and oval egg is covered with an exceedingly hard

and glossy shell, with a white edge enclosing a black line on one side and a brown top beautifully sculptured, which acts as a sort of stopper to each box-like egg. The eggs are not glued or fastened to any object, but are simply dropped to the ground, where they remain until the succeeding year; sometimes they do not hatch until the second year. The young walking-sticks resemble the old ones except in size; they are also brighter in color, and molt but twice.

This species is a very general feeder, and the foliage of all our trees and bushes, excepting the evergreens, is eaten. Sometimes these insects become very numerous, and in such a case can seriously injure our shade and forest trees. Being insects with chewing mouths, and very slow in all their motions, they can easily be killed by poisoning their food with some of the arsenical poisons.

The *Acrididæ* and the two following families of orthoptera form the section SALTATORIA or JUMPERS. All insects belonging to this section have their hind legs fitted for jumping, the femora being either very much stouter or longer, or both stouter and longer than those of the other legs. The peculiar parallel "fish-bone" markings seen upon them is produced by the attachment of the powerful muscles inside. The females in this section are usually furnished with more or less prominent ovipositors, and the wings of the immature forms (pupæ) are in an inverted position. Many species, especially among the *Acrididæ*, possess in the adult state only rudimentary wings and resemble immature insects. By carefully looking at the wings it will be seen that the adult insects, even the short-winged ones, have the tegmina in the proper position, while in the immature insects they are folded beneath the wings; the principal veins of the wing-covers and wings of the immature insects curve downward instead of upward.

FAMILY V.

LOCUSTS OR SHORT-HORNED GRASSHOPPERS.

(*Acrididæ*).

The members of this family differ from other *Saltatoria* in having the six to twenty-four jointed antennæ shorter than the body. They are either filiform, flattened, or ensiform, rarely clavate. The ovipositor of the female is short, composed of four plates. The first segment of the abdomen possesses on each side a supposed organ of hearing. Anterior and middle legs about equal, or nearly so, in length, much shorter than the posterior pair, which is fitted for jumping. The tarsi are three-jointed, the first joint, usually the longest and much longer than the second, has the underside marked by two cross impressions, which, when seen on this side, give it the appearance of being composed of three pieces. Wing-covers, when not in use, rest partly horizontal on the back of the abdomen, and partly deflexed against the sides. Most of the species possess wings, but in a few these organs are wanting. The head is usually short and extended horizontally in two of the sub-families. Immediately under the vertex, but in some cases above it, there is on each side a little space bounded by elevated ridges. These spaces are called *lateral foveolæ*, and their variations in form afford characters much used in classification. The front is generally traversed by three vertical keels or *carinæ*. The pronotum is divided into four lobes by three more or less well marked transverse sutures, and is also frequently furnished with a median crest. The hind tibiæ carry upon the upper side two rows of spines; the numbers of these is of use in distinguishing species; the presence or absence of the last spine in the outer row is of much greater importance. Besides these spines there are four articulated spurs, which are situated in two pairs, one on the outer and one on the inner side of the tibiæ. In the male the ventral surface of the abdomen consists of nine segments, in the female there are but

eight. The caudal end of the body in the female has four horny appendages, the ovipositor; in the male the ventral pair of appendages is represented by a single plate.

As mentioned before, the males of many species of *Acrididæ* possess stridulating organs.

Locusts deposit their eggs in oval or bean-shaped masses covered with a glutinous substance. As this method of laying eggs has been described more in detail when giving the description of our migatory species it is not necessary to give it here, especially as the life-histories of our locusts are nearly alike. The number of eggs deposited by the different species varies greatly, some egg-masses containing from twenty-five or thirty to sixty or more, and as in many cases several such masses are produced by each female, the number of offspring can be quite large. Other species, as the Coral-winged Locust (*Hippiscus tuberculatus*) deposit all eggs (125 to 130) in one single mass. The different species also select different times and places for this purpose, some digging holes in the fall, others in spring, some selecting hard gravel, elevated sandy spots, or well traveled roads, while some select soft wood for oviposition.

This family contains a large number of species, all more or less injurious. Even the non-migrating species seen everywhere during the warmer part of the year are very destructive, and deserve the full attention of the farmer. Yet as a very general rule nothing is done to reduce their number, nor are they even considered very injurious, excepting in seasons of drought, when every blade of grass is devoured. Damp and moist weather is injurious to most species of locusts, and is undoubtedly the most effectual natural agent to keep them in check. Extreme changes during winter seem to destroy the vitality of the eggs.

All young locusts are greedy feeders, and, considering their size, devour immense quantities of food. They molt their skin from three to five times. The wings, in form of small wing-pads, appear early and gradually, and become

larger with each molt. The pupa is not very different from the larva, only a little larger, but just as active and hungry as it or the adult.

Prof. Comstock gives the following classification:

A. Pulvilli present between the claws of the tarsi; pronotum never extending over the abdomen.

B. Prosternum unarmed.

C. Vertex and front of head meeting at an acute angle; vertex extending horizontally; front strongly receding..... 1. *Tryxalinæ.*

CC. Head rounded at the union of the vertex and front; front perpendicular, or nearly so.

D. The terminal spine of the outer row of the posterior tibiæ wanting; second abdominal segment smooth. ..... 2. *Œdipodinæ.*

DD. The terminal spine of the outer row of the posterior tibiæ present; second abdominal segment granulated on the sides ..... 3. *Eremobinæ.*

BB. Prosternum tuberculate, or mucronate, or produced into a cone.

C. Head rounded at the union of the vertex and front; front slightly receding; antennæ filiform ..... 4. *Acridinæ.*

CC. Vertex extending horizontally in front of the eyes; front strongly receding; antennæ more or less flattened..... 5. *Opomalinæ.*

AA. No pulvilli between the claws of the tarsi; pronotum extending over the abdomen..... 6. *Tettiginæ.*

Prof. Scudder, in his "Guide to Orthoptera," has only four sub-families; he unites 3 with 2, and 5 with 1.

Prof. Fernald gives the following simple table of the sub-families found in New England:

1 { Pronotum extending back to the tip of the abdomen.....*Tettiginæ.*
{ Pronotum not extending back to the tip of the abdomen..... 2.

2 { Prosternum with a prominent spine.....*Acridinæ*.
  { Prosternum not spined, or with only an oblique tubercle.....3

3 { Face very oblique.....*Tryxalinæ*.
  { Face not oblique, or but slightly so.....*Œdipodinæ*.

SUB-FAMILY TETTIGINÆ.

GROUSE LOCUSTS.

These very small locusts possess a very unusual form, having the pronotum prolonged to such an extent that it projects to or beyond the abdomen. The head is deeply set in the pronotum, and the prosternum is expanded into a broad border partially enveloping the mouth. The short antennæ are very slender. The wing-covers are rudimentary, and resemble small rough scales; the wings are very large in proportion. Members of this sub-family possess no pulvilli between the claws of their tarsi.

Tettiginæ are very common in some localities, and especially near the shores of our lakes. Here they feed upon such lowly organized plants as lichens, molds, etc., in fact they eat mud containing decayed vegetable matter, and in this way they act very differently from other members of the order of orthoptera. Being usually of a dark color, which blends with the soil upon which the insects rest, they can not readily be seen; nor are they easily captured, as they are very active and possess enormous leaping powers.

There are two groups of *Tettiginæ:*

A. Anterior femora more or less compressed, carinate above; antennæ with 12-14 joints.....*Tettigiæ*.

AA. Anterior femora distinctly and broadly sulcate above; antennæ with 15-22 joints.....*Batrachideæ*.

We possess three genera of *Tettigiæ* in Minnesota:

A. Median carina of pronotum cristiform; superior lateral sinus (at insertion of tegmina) shallow, not nearly so deep as the inferior sinus.....*Nomotettix*.

AA. Median carina of pronotum low; superior lateral sinus nearly as deep as the inferior sinus.

b. Vertex of fastigium generally broader than the eyes, projecting beyond them, generally angulate anteriorly.....*Tettix.*

bb. Vertex of fastigium narrower than the eyes, and not projecting beyond them, usually truncate anteriorly.....*Paratettix.*

The genus *Tettigidea* is the only one found in Minnesota that belongs to the *Batrachideæ.*

GENUS *Nomotettix* Morse (1894).

Lateral lobes of the pronotum with the postero-dorsal sinus shallow, about one-half the depth of the antero-ventral sinus. Pronotum advanced upon the head, rather sharply tectiform. Occiput of head with a pair of nipple-like or mammillate protuberances between the posterior portion of the eyes and the median line.

Nomotettix parvus Morse.

Small. Vertex of head projecting in advance of eyes about two-thirds the length of an eye, the anterior margin obtuse-angulate, its sides straight, rounding shortly into sides of crown, the mid-carina showing from above as a very small, slightly projecting tooth. Mid-carina low on the crown, disappearing opposite the middle, or middle of the posterior half, of the eyes. Profile rounded or round-angulate at top, deeply excavate opposite eye, sub-protuberant opposite lower border of eyes, the face more retreating than in *cristatus.* Sides of crown sub-parallel, slightly excavate opposite anterior portion of eyes. Mammillæ of occiput scarcely distinct, pronotum sharply tectiform, the mid-carina lower and less arched longitudinally than in *cristatus;* anterior margin of dorsum projecting but little over the head, obtuse-angled, the sides straight or very slightly excavate. Surface scabrous.

Fig. 62. — *Nomotettix parvus.* Original.

The specimens from which Prof. Morse described this interesting insect were

found near St. Anthony Park. The insect, illustrated in Fig. 62, must be uncommon, or very local, as no others have been discovered; the line gives its natural length.

GENUS *Tettix* Charpentier (1841).

Size small; form slender; head small, eyes globular, protruding; pronotum compressed anteriorly, median carina distinct, hind portion extending back over the abdomen to or beyond its extremity, and terminating in a long narrow point; wing-covers very short; wings fan-like, well developed, almost as broad as long, and as long or longer than the abdomen; lower anterior angle of sides of pronotum angulated and bent inward.

Tettix granulatus Kirby.

Anterior border of vertex considerably advanced in front of eyes, angulate, the apex very slightly rounded, or rarely with the mid-carina projecting a trifle. In profile the face is quite retreating, the vertex considerably advanced, sinuate opposite the eyes, and moderately protuberant opposite antennæ. The eyes are the least prominent in this of any species, and the body more slender. It is liable to be mistaken for *T. ornatus* only, but the outlines of the profile and vertex, considered together, need leave no doubt of the species.

Measurements.—Length of body, female, 15 mm., male, 12 mm.; pronotum, 13 mm.; hind femora, 6 mm.

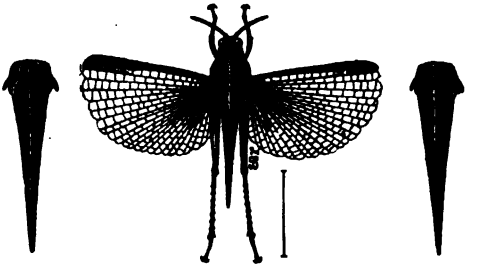


Fig. 63.—*Tettix granulatus* and two varieties. Original.

This is one of our most common species, found from April to late in September; it hibernates among rubbish and loose bark, but is more or less active during warm days. It is very common on the sandy shores of Lake Superior. It varies greatly in color and markings, some having a very distinct bright yellowish dorsal stripe extending from tip to tip. The insect, and two varieties, are shown in Fig. 63.

Tettix ornatus Say.

The name *ornatus* expresses well the appearance of this fine insect, which has numerous styles of ornamentation. Perhaps the name is a collective and not a specific one. Morse unites with *ornatus* the *triangularis* of Scudder, which differs from it by having the pronotum slightly extending beyond the tip of the abdomen and not prolonged into a slender point as in *ornatus*. The pronotum is very variable in length, in some reaching the end of the hind femur, in others passing it by 3.5 mm.; the wings are equally variable, and usually least developed proportionally in those specimens with the shortest pronotum. It is impossible to draw any line between these two forms, although the typical forms are quite distinct.

The species is readily recognizable from the characters of the vertex. This projects in front of the eyes, is somewhat rounded anteriorly and the mid-carina forms a distinct projecting tooth. The profile is rounded-angulate above, excavate opposite the eyes and protuberant opposite the antennæ. Very rarely a specimen is met which in a dorsal or a profile view approaches *granulatus* closely, but any doubt of its identity is usually dispelled by an examination of it from both directions.

Measurements.—Length of body, 9 to 10 mm.; pronotum, 9 to 11 mm.; posterior femora, 5 mm.

FIG. 64.—*Tettix ornatus*. Original.

This cinereous insect, marked with yellowish and black, is by no means uncommon, being found from April till October, yet it is very difficult to secure. Sometimes early in October, when the nights are already very cool, this insect may be found in large numbers upon wooden sidewalks, which warm up earlier in the morning than the ground. Here they squat, evidently enjoying the warmth. A common form of it is shown in Fig. 64.

Tettix triangularis Scudder.

Variety *brachyptera* occurs in Minnesota, but has not been seen by the writer.

Tettix obscurus Hancock.

Form slender; pronotum flattened on the dorsum, and the lower margins of the lobes strongly distended laterally; surface of dorsum finely rugose. Wings overreach apical process.

A number of this species were captured early in spring in an open field near St. Anthony Park.

Tettix Luggeri Hancock.

Vertex slightly advanced in front of the eyes, anterior border convexed, mid-carina distinct; in profile face moderately ampliate opposite the antennæ, apex less prominent, frontal costa nearly straight, not excavate, with the vertex together rounded angulate. Pronotum tectiform, truncate anteriorly, median carina percurrent and prominent, apical process long, subulate, passing beyond the knee of hind femora. Wings reaching beyond the end of process.

A slender form allied to *T. granulatus*, but differing principally in the character of the vertex and the frontal costa which is not at all excavate. Entire length, female, 15 mm.; hind femora, 6 mm.; pronotum, 14.5 mm.

GENUS *Paratettix* Bolivar (1887).

A description of the genus has been given before.

Paratettix cucullatus Burm.

Fig. 65.—*Paratettix cucullatus.* Original.

This species (Fig. 65) is easily recognized by the form of the vertex. From above this appears about equal in width to one of the large and prominent eyes, and does not project in advance of them; its front margin is slightly hollowed, the concavity being divided by the mid-carina which projects a little. In profile the frontal costa is slightly sinuate opposite the eyes and strongly protuberant opposite the antennæ. The crown of the head is channeled longitudinally on either side of the mid-carina, the sulci being stopped abruptly opposite the hinder portion of the eyes by a pair of transverse, sometimes slightly oblique, ridges. This character is found in several species of this genus and in this species appears at a very early stage, showing distinctly in specimens only 3 mm. in length. The body is less compressed than in *granulatus*, being, in truth, depressed rather than compressed. The pronotum is advanced upon the head to the eyes, and the median carina is obsolete on the anterior portion; the posterior process extends 2 to 3 mm. beyond the hind femora, exceeded by the wings, and is very constant in proportions.

Measurements—Length of body, 10 mm.; pronotum, 12 mm.; posterior femora, 6 mm.

This species is very abundant in low fields fairly free from vegetation. It deposits eggs, like most of the locusts, in pod-like masses in the earth; 25 to 32 eggs have been found in each pod. The eggs hatch in about sixteen days into pale yellowish-white insects, with large and swollen heads, red eyes and short antennæ.

GENUS *Tettigidea* Scudder (1862).

Size small; form robust and clumsy; head large and broad, with the front less sloping and with median ridge of

the face more prominent than in the genus *Tettix* and *Paratettix;* antennæ 21 to 22 jointed; lower anterior angle of sides of pronotum rounded and not bent inward as in *Tettix;* front border of the pronotum thrust forward and partly concealing the head; median carina straight, somewhat curved anteriorly; lateral carina less prominent than in *Tettix*, and not so strongly bent inward in advance of the broader portion of the pronotum.

Tettigidea lateralis Say (*pennata*) Morse.

Fig. 66.—*Tettigidea lateralis.*—Original.

Head and sides of body blackish-brown; hind femora with a rather large ochraceous spot outside about the middle; underside of body dirty yellow; top of pronotum light or dark testaceous, sometimes the same color as the sides of the body, with a testaceous border. In the male the face and lower anterior portion of the pronotum are yellow. Wings and pronotum extending beyond the abdomen, wings somewhat longer than the pronotum. The insect is illustrated in Fig. 66.

Measurements.—Male, length of body, 10 mm.; pronotum, 11 mm.; posterior femora, 6 mm. Female, length of body, 14 mm.; pronotum, 15 mm.; posterior femora, 7.5 mm.

Tettigidea polymorpha Burm.

This seems to be simply a form of *lateralis,* distinguished from it by having shorter pronotum and wings. Otherwise they are either the same or very closely allied.

Both species are common in Minnesota, but especially *polymorpha* (*parvipennis* Harr.).

SUB-FAMILY TRYXALINÆ.

Prof. Jerome McNeill has quite recently published an excellent account of the insects forming this sub-family. Those

interested should consult his "Revision of the Tryxalinæ of North America." It is fully illustrated.

This sub-family is easily separated from all others with the exception of the Œdipodinæ, in which exist genera that form a perfect connecting link.

The Tryxalinæ differ from the other members of the Acrididæ by possessing a conical and elongated vertex, the front strongly receding, flattened antennæ, which are inserted between the middle of the eyes, or farther from the mouth than their middle. The eyes are usually longer than that part of the genæ below them; the posterior lobe of the pronotum is usually shorter than the anterior part; the median carina is not at all crested, and the last spine of the outer row of the posterior tibiæ is wanting. The difference between this family and the Œdipodinæ is in the joining of the vertex and front, as indicated in the table of sub-families given before.

Most members of this sub-family of orthoptera are grass-loving insects, which delight to rest upon sandy spots surrounded by these plants. They strongly contrast in this respect with the Œdipodinæ, which generally prefer barren hillsides, dusty roads and other localities characterized by scanty vegetation. The short wings of the former are never brilliantly colored, nor are their tegmina large and showy, as this would not blend well with their surroundings. Yet the colors, even in the same species, are quite variable, brown or green tints predominating.

GENERA OF TRYXALINÆ FOUND IN MINNESOTA.

A. Head equaling, never exceeding, the pronotum in length. Antennæ triquetrous or strongly depressed at base; pronotum with the lateral lobes vertical and straight and the lateral carina not at all sinuate; median carina of the pronotum generally cut much behind the middle; the disk plain and unstriped.

B. Spines of the exterior margin of the posterior tibiæ 15 or more; posterior margin of the disk of the pronotum mostly straight, scarcely angled or rounded.....*Pseudopomala.*

BB. Spines of the exterior margin of the posterior tibiæ less than 15; posterior margin of the disk of the pronotum obtusely angled or rounded.

C. Tegmina exceeding the abdomen considerably in both sexes (in some large females but little); lateral carinæ of the pronotum quite as distinct as the median; spurs at the apex of the posterior tibiæ on the inner side about equal. *Tryxalis.*

CC. Tegmina not exceeding the abdomen, even in the male.....*Opeia.*

AA. Antennæ never triquetrous, sometimes plainly depressed basally or acuminate, most commonly filiform, rarely clavate; pronotum with the lateral lobes less distinctly vertical, with the lateral carina very rarely quite straight, but gently or strongly sinuate near the middle; median carina of the pronotum generally cut in or not far behind the middle.

B. Scutellum of the vertex with a distinct median carina which is usually a coarse raised line stronger anteriorly.

C. Spurs on the inner side of the posterior tibiæ very unequal, the apical spur being twice as long as the other; antennæ very greatly exceeding the head and pronotum, somewhat clavate.....*Eritettix.*

CC. Spurs on the inner side of the posterior tibiæ about equal in length.

D. Spines on the exterior margin of the posterior tibiæ 19-21.....*Syrbula.*

DD. Spines on the exterior margin of the posterior tibiæ not exceeding 15. Median carina of pronotum cut much behind the middle by the principal sulcus..*Chloëaltis.*

BB. Scutellum of the vertex with no distinct median carina.

C. Posterior margin of the metazone angulate. Tegmina usually much shorter than the abdomen, with the ulnar area not very much wider than the discoidal area....*Dichromorpha.*

CC. Posterior margin of the metazone rounded or not distinctly angulate. Tegmina not much shorter than the abdomen, with the ulnar area very wide and several times as broad as the discoidal area.

D. Hind tibiæ never red.....*Orphula.*

DD. Hind tibiæ red.

E. Median carina of the pronotum high and sharp, cut by the principal sulcus in, or plainly in front of, the middle. Intercalary vein very strong. Apical spurs on the inner side of the posterior tibiæ unequal.....*Mecostethus.*

EE. Median carina of the pronotum rarely cut plainly in front of the middle, in this case it is not high and sharp, or the intercalary vein is not strong.

F. Tempora elongate, narrow, from two to four times as long as broad. The apical spur on the inner side of the posterior tibiæ is much less than twice as long as the one beside it.

G. Antennæ filiform....*Stenobothrus.*

GG. Antennæ clavate..*Gomphocerus.*

FF. Tempora short, little longer than broad or, when twice as long, the apical spur on the inner side of the posterior tibiæ is twice as long as the one beside it.....*Eremnus.*

GENUS *Pseudopomala* Morse (1896).

This insect is included by McNeill in the Tryxalinæ, but has since been removed by Scudder to the Acridiinæ.

"Vertex horizontal, longer than broad, semi-elliptical, medianly convex with a very distinct carina, laterally sulcate (female) extended into lamina (male), with the margins limited by lateral carinæ. The lateral foveolæ are wanting. The frontal costa is sulcate throughout with slightly divergent heavy lateral carinæ except at the immediate apex where it is much constricted. The face is very declivent and straight or a very little sinuate on account of the prominence of the frontal costa between the antennæ. These are very slightly triquetrous and very much flattened and expanding basally, equaling the short diameter of the eye nearly (male) or quite (female) and strongly acuminate. They equal the head and pronotum in length (female) or greatly exceed them (male). The pronotum is but little longer than the head. Its disk is nearly plain, slightly elevated toward the median carina which is distinct and cut only once much behind the middle by the principal sulcus, which alone is apparent upon the disk. The lateral carinæ are distinct, parallel, cut by the principal sulcus only. The posterior margin of the metazone is straight. The lateral lobes of the pronotum are vertical, slightly convex above, with the anterior and posterior margins strongly oblique, the one straight, the other sinuate just above the posterior lower angle, which is sharp and sub-rectangular. The lower margin is nearly straight and horizontal. The mesosternal lobes are separated by a space longer than broad (female) or by a linear ridge with a deep

pit on either side (male). The wings in both sexes and the tegmina (female) are abortive or they are well developed. In the male the scapular area is enlarged with prominent veins. The posterior femora are slender, not banded. The posterior tibiæ have the apical spurs on the inner side not very unequal. The last ventral segment of the male is horizontal, elongate, conical and four times as long as the penultimate segment. The valves of the ovipositor are exerted, the lower ones furnished with a strong lateral tooth, the upper ones with two distinct basal teeth."

Pseudopomala brachyptera Scudder.

Brown, dotted faintly above with black. A very faint and obscure dark stripe extends from the lower border of each eye along the side of the pronotum. Hind femora dotted with black along the upper edge; terminal lobe dark. Spines tipped with black. The female, which is more uniformly brown than the male, is dotted with numerous

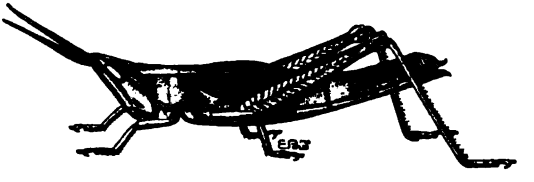


Fig. 67.—*Pseudopomala brachyptera*, Original.

minute dusky specks, and has shorter wing-covers and wings. Fig. 67 shows this insect.

MEASUREMENTS.—Length of body, male, 23.5-27 mm., female, 27.5-29.5 mm.; of long winged tegmina, male, 15.5-17 mm., female, 18-22 mm.; of tegmina, male, 9-12.3 mm., female, 7-12 mm.; of hind femora, male, 13.5-15.5 mm., female, 14-19 mm.; of head and pronotum, male, 7.3-8.6 mm., female, 7-12 mm.; of antennæ, male, 9.5-11.3 mm., female, 8.5-10 mm.

This is a very uncommon insect in Minnesota, and only one pair was found late in summer upon Gray Cloud Island. Closer collecting will doubtless show that it occurs also in other parts of the state, as the species has an extended range, occurring from Illinois to New York, in New England, and from Iowa to Utah.

GENUS *Opeia* McNeill.

Vertex nearly horizontal, shorter than the distance between the eyes, convex, a little sulcate behind the prominent lateral carinæ which meet at an angle of about 90 degrees. Median line distinct. Lateral foveolæ not visible from above, they are small sulci which extend from the ocelli toward the vertex and are not clearly separated from the front. The frontal costa is sulcate except at the apex, and its margins are slightly and regularly expanded downward. Seen from the side, the face is straight and strongly declivent. The antennæ are considerably flattened basally and regularly acuminate, distinctly shorter than the head and pronotum. The pronotum has the disk nearly plain, being slightly elevated to the median carina. This and the lateral carinæ are unusually heavy and distinct and all three are cut by the principal sulcus only much behind the middle. The lateral carinæ are very slightly divergent from the middle of the pronotum to the posterior margin which is roundly angulate. The lateral lobes of the pronotum are not quite so high as long; they are nearly perpendicular, being very slightly convex above, and they have a nearly horizontal carina extending from the middle to the postrior margin. They have the anterior and posterior borders strongly oblique with the lower margin nearly straight. There is no posterior tubercle. The mesosternal lobes are separated (female) by a space about as long as wide, the metasternal lobes by a space longer than wide (female) or nearly contiguous (male). The tegmina are little shorter than the abdomen (female). The discoidal area is occupied by a weak

intercalary vein The scapular area is decidedly expanded in the male, and filled with a single series of moderately strong curved cross veins. The posterior femora are not slender, they extend somewhat beyond the end of the abdomen. The valves of the ovipositor are but little exerted.

Opeia obscura Thos.

This is a western species, but a male, female and pupa were found late in October in the extreme western part of the state, in Brown's Valley. They occurred in some numbers in a swampy place, but were mistaken for common insects, hence but few were captured. It is a very variable species, with a brown or green dorsum, either plain or with a streak of fulvous along the median vein. The sides are marked by a stripe extending backward from the eye, widening and generally becoming more obscure. When most distinct, this stripe consists of five parts, as follows: an upper streak of brown or fuscous below the lateral carinæ, below this a lighter streak followed by a white line, and still below this the light and dark streak, repeated. These five elements of the lateral stripe vary greatly in intensity of coloration, but can nearly always be seen, and in all cases the lower fifth of the pronotum at least is brown. The tegmina have the discoidal area occupied by a row of large usually distinct quadrate fuscous spots and the scapular area contains a whitish mark.

This interesting species is illustrated in Fig. 67½.

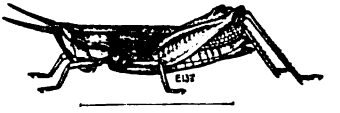


Fig. 67½.—*Opeia obscura*. Original.

GENUS *Eritettix* Bruner (1889).

Head conical, occiput not elevated, furnished with three carinæ, one median and two supplementary; the former ex-

tends from the pronotum to the tip of the vertex where it is enlarged, the latter from the pronotum to a point opposite the anterior margin of the eyes where each suddenly bends to join the lateral carinæ of the vertex. The vertex is convex and equilaterally triangular. Its lateral carinæ are generally distinct, sometimes heavy, raised lines. The lateral foveolæ are present below the vertex, sub-triangular, not deeply impressed, sometimes not very apparent because of the slightness of the lower carinæ and because of their small size. The frontal costa has its sides somewhat regularly divergent from the vertex to the clypeus, generally a little constricted about the ocellus and slightly sulcate for a greater or less distance above this point but never sulcate to the vertex. The antennæ are thick, generally somewhat flattened at the base and clavate at the apex, which is bluntly acuminate and scarcely longer than the head and pronotum. The pronotum has the lateral and median carinæ distinct and cut once only by the principal sulcus decidedly behind the middle. In addition to these usual carinæ are two supplementary carinæ on either side about midway between the median and lateral carinæ. The posterior margin and the lateral lobes of the pronotum are very obtusely angulate. The lateral lobes of the pronotum are about as high as they are long, with the anterior border decidedly or little more oblique than the posterior They have a more or less distinct carina which runs obliquely from the first sulcus to or toward the posterior margin. The lower anterior angle is obtuse, the posterior is rectangular. The lower margin is straight and horizontal on the posterior half, straight and slightly ascending on the anterior half. The mesosternal lobes are separated by a space much wider than long, and the metasternal lobes by a space longer than wide, in both sexes. The tegmina and wings are usually well developed, extending much beyond the middle of the wing and the scapular area in the male is widened and filled with a series of rather weak and not very regular oblique veins. There is no intercalary vein and

the dividing soon unites with the plicate vein. The ovipositor is nearly included. The posterior femora are more than usually heavy, with the apex extending beyond the abdomen, and they are never banded. The posterior tibiæ are obscure or reddish, never blue, and the inner apical spur is about twice as long as the one behind it.

Eritettix tricarinatus Thos.

This is also a very uncommon insect, but a few were found with other insects in the hopper-dozers used in Otter Tail county, Minn. It varies greatly in color; some are almost uniform brown, with a darker longitudinal stripe on each side of head and pronotum, edged with a white line on their outer side on the pronotum. This white line seems to be found in all color-forms. In many specimens the color below this line is bright green, and the same color is found on the anterior edges of the wings and on the hind legs. Five darker spots, sometimes confluent, are found in the middle field of the wing-covers. The insect is illustrated in Fig. 68.

Fig. 68.—*Eritettix tricarinatus. Original.*

Length 21.75 mm.; of tegmina, 14 mm.; of posterior femora, 12.5 mm.

Syrbula admirabilis Uhl., which may also occur in the southern part of the state, and has been reported from Winona, has not been seen by the writer, and the occurrence at that place, though possible, is doubtful.

GENUS *Chloëaltis* Harris (1852).

Vertex triangular, a little declivent, not extending in front of the eyes as much as the distance between the eyes, convex, more or less sulcate, with the lateral carinæ little elevated and the median carina slight but never entirely

wanting. The lateral foveolæ are wanting. The frontal costa is more or less rounded above the ocellus, plain or very faintly sulcate below with the sides sub-parallel. The antennæ are decidedly flattened at the base and much longer than the head and pronotum together, in the male as long as the hind femora. The face seen from the side is nearly straight. The pronotum has the disk plain with the three carinæ equally distinct and cut much behind the middle with the last transverse sulcus. The lateral carinæ are plainly (male) or strongly (female) curved. The posterior margin of the metazone is straight or gently curved, not angulate. The lateral lobes of the pronotum are longer than high, with the anterior and posterior margins straight and strongly and equally oblique, and with the lower margins horizontal or slightly descending posteriorly, more decidedly ascending anteriorly. Mesosternal lobes separated by a space much broader than long, the metasternal lobes by a space broader than long (female) or about as broad as long (male). The tegmina are generally abortive (female) or well developed (male). The scapular area is unusually expanded, especially near and beyond the middle in the male (and in the female to a less extent when the tegmina are not abortive), and is filled with a series of strong oblique cross-veins. The discoidal is as broad as the ulnar area, and the intercalary vein is present. The posterior femora are rather slender or moderately robust and more or less distinctly banded above. The posterior tibiæ have the apical spurs on the inside about equal.

THE SPRINKLED LOCUST.

(*Chloëaltis conspersa* Harr.).

Light reddish-brown, sprinkled with black spots; a black line on the head behind each eye, extending on each side of the thorax on the lateral elevated line; wing-covers oblong-oval, pale yellowish-brown with numerous small

darker brown spots; wings about one-seventh of an inch long, transparent, with dusky lines at the tip; hind tibiæ pale red, with the spines black at the end. Length nearly nine-tenths of an inch. The male differs greatly from the female in coloration, having the lateral lobes of the pro-

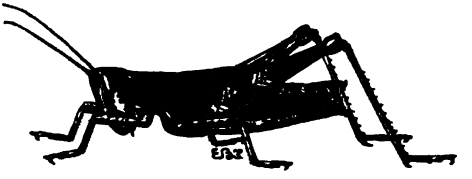


Fig. 69.—*Chloëaltis conspersa*, female. Original.

notum black. Wing-covers and wings are variable. Fig. 69 shows the female, and Fig. 70 the male.

This insect, although not common, is found throughout the state, and has been frequently caught in large numbers in hopper-dozers. It is found very early in the season (June 28), and lasts until late in the autumn (Oct. 3).

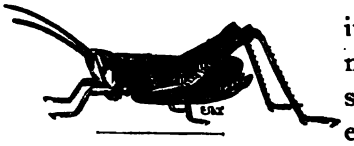


Fig. 70.—*Chloëaltis conspersa*, male. Original.

The Sprinkled Locust differs in its mode of oviposition very much from the majority of other species. Instead of laying the eggs in the ground, as is usual, it selects rotten stumps or other slightly decayed wood for this purpose. Blatchley, in the Canadian Entomologist, writes as follows: "On Aug. 11, 1893, I discovered a female in the act of boring a hole in the upper edge of the topmost board of a six-plank fence. The abdomen was curved downward, and the forcipate valves of the ovipositor were used as pinchers with which small pieces of the wood were broken off. When discovered the abdomen was inserted nearly one-half an inch into the pine board and the upper edge of the opening about the sides of abdomen was covered with small pieces of wood, just as the dust or borings will accumulate about

the edge of a hole which a carpenter is boring. Many holes were found."

The females of this species can easily be confused with the brown females of the next species, the Short-winged Green Locust, from which they may be separated by the slight median carina of the vertex.

GENUS *Dichromorpha* Morse (1896).

Vertex much shorter than broad, somewhat declivent, convex, but more or less sulcate behind the distinct elevated lateral carinæ. These are straight or gently curved and meet at an angle of 90 degrees or more in a blunt point. The median carina is entirely wanting, as are the lateral foveolæ. The frontal costa is sulcate above and below the ocellus, with the sides gently divergent downward, more or less constricted just below the ocellus and near the vertex. The face seen from the side is nearly straight. The antennæ are a little longer (male) or scarcely as long as (female) the head and pronotum. The disk of the pronotum is plain with the three carinæ very nearly straight and parallel. All are cut distinctly behind the middle by the very faint principal sulcus. The first and second transverse sulci are not visible upon the disk. The lateral lobes of the pronotum are perpendicular, longer than high, with the anterior and posterior margins straightly oblique, the latter plainly sinuate and the lower margin a little descending posteriorly, more strongly ascending and sinuate anteriorly. The lobes of the mesosternum are separated by a space broader than long (female) or as broad as long (male). The lobes of the metasternum are separated in the female by a space as long as broad, in the male they are contiguous. The tegmina are generally abortive sometimes well developed, in which case the scapular area is not expanded. The anal field of the tegmina meets the discoidal field at an angle. The posterior femora are stout and not banded. The posterior tibiæ are obscurely colored, with the apical spurs on the inner side not

very unequal. The valves of the ovipositor are moderately exerted.

THE SHORT-WINGED GREEN LOCUST.

(*Dichromorpha viridis* Scudder).

Fig. 71.—*Dichromorpha viridis*. Original.

Wing-covers shorter than the body, a little longer than the wings. The insects vary greatly in color, the brown outnumbering the green ones. The top of head and pronotum green; sides of head and pronotum dirty brown, with a horizontal black band behind the eye, extending over the pronotum; front of head yellowish-brown; fore and hind legs reddish-brown; mesothoracic legs green, spines of tibiæ tipped with black; wing-covers above green, upon the sides brown; body beneath yellowish. The female varies from bright pea-green to a uniform rusty-brown, with a dark band behind the eye, as in the male; upon the top of the head a dark band extends from either side of the vertex, curving inwards and then outwards to midway between the median and lateral carinæ; hind tibiæ reddish-brown. The males are much smaller, have the back green and rest of body brown. Fig. 71 shows the female of this insect.

Length of male about 18.75 mm.

This insect has been found in a number of places in the central and southern portions of the state, but is not common. It occurs in open wet spaces covered with coarse grass, and has been taken as early as July 22 on Gray Cloud Island.

GENUS *Orphula*. Stål. (1873).

Vertex nearly horizontal, never extending in front of the eyes a distance greater than its own width, always more

or less sulcate, with or without a faint median carina. The lateral foveolæ are obsolete or distinct, elongate triangular, or linear, not visible from above. The frontal costa is plain or sulcate with the sides nearly straight and very moderately divergent. The face is nearly straight or a little arcuate, never at all sinuate. The antennæ are filiform, sometimes depressed and acuminate at the apex. The pronotum has the disk nearly plain, with the median carina cut in or behind the middle. The lateral carinæ are generally decidedly or strongly sinuate, rarely nearly straight and divergent from the front border, or from the first and second sulcus. Very rarely they are nearly parallel. The lateral lobes of the pronotum have the anterior border decidedly oblique and straight or a little arcuate, the posterior border is less oblique and more or less sinuate and the lower border is decidedly angulate in the middle. The mesosternal lobes are separated by a space broader than long (female) or about as broad as long (male), and the metasternal lobes by a space not broader than long (female) or they are contiguous (male). The tegmina and wings are well developed, a little shorter or much longer than the abdomen. The former are very narrow, with the scapular area not more expanded in the male than in the female. The discoidal area is destitute of the intercalary vein and the ulnar area in the male is sometimes much widened and regularly reticulate. The posterior femora are moderately slender or rather heavy. The apical spurs on the inner side of the posterior femora are never very unequal. The valves of the ovipositor are moderately exerted.

THE SPOTTED-WINGED LOCUST.

(*Orphula pelidna* Burm.).

This is the insect perhaps better known as *Stenobothrus maculipennis* Scud. It is very variable, and a description to cover all forms can not be well formulated. Head and

top of pronotum green (brown in others); a broad reddish-brown band extends from the eyes to the posterior side of the pronotum, limited above by the lateral carinæ, which are white. Sides of the pronotum below the band brownish or dull yellowish. Wing-covers extending beyond the end of the abdomen green, with a row of square, black spots along the middle, and a few irregularly scattered smaller black spots.

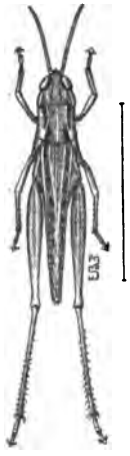


Fig. 72.—*Orphula pelidna*. Original.

It is a rather common insect in sandy or barren spots, and occurs in fairly large numbers along the bluffs of the Mississippi River, where it is fully grown about the first of August. Fig. 72 shows this insect.

The structural characters of the head, vertex and pronotum are the best means of separating it from others of the same genus.

Length, male, 16-19 mm., female, 20-24 mm.; tegmina, male, 14-17.5 mm., female, 18-20 mm.; antennæ, male, 7-10 mm., female 8.5-10 mm.; posterior femora, male, 9.5-11 mm., female, 12-14 mm.

Orphula speciosa Scud.

(*Stenobothrus æqualis* Scud.).

This is also a rather common locust, found everywhere on dry soil; it is also variable in coloration. It was first described by Scudder from Minnesota specimens.

Vertex of the head quite broad, not expanding at the sides; apex not rounded; the sides of the angle straight; edges upturned considerably; a slight median grove; no lateral foveolæ. Sides of the pronotum approximate, constricted in the middle; lateral carinæ not so prominent and sharp as the median. Wings as long as the tegmina, extending beyond the tip of the abdomen.

Brown above, pale yellow beneath. Face yellowish-brown; parts of the mouth pale-yellow. Antennæ reddish-

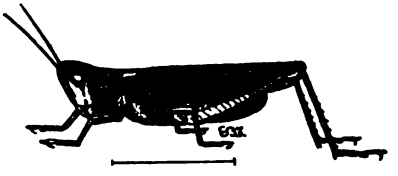


Fig. 73.—*Orphula speciosa, male.* Original.

brown. A narrow curved streak on the top of the head from the inner edge of the eye to the lateral carinæ; a narrow, straight, white streak from the eye to the lateral carinæ; the upper half of the sides of the pronotum brownish, darkest above. Legs yellowish-brown; spines of the tibiæ tipped with black. Tegmina brownish at base; apical half pellucid, with rosaceous nervures; costa with a dark streak beyond the middle.

Length, male, 14-15 mm., female, 20-21 mm.; tegmina, male, 12-13 mm., female, 12-16 mm.; antennæ, male, 5-6 mm., female, 6 mm.; posterior femora, male, 9 mm., female, 11 mm. Both sexes are shown in the illustrations (Fig. 73 male, Fig. 74, female).

GENUS *Stenobothrus* Fischer (1843).

Vertex triangular, obtuse (of the male acute), with the foveolæ, which are visible from above, narrow, oblong, rhomboidal. Antennæ filiform. Frontal costa convex. Pronotum with the disk almost plain, the median carina distinct and cut by the principal sulcus only, and the lateral carinæ straight or more or less arcuate or sinuate. The lateral lobes of the pronotum about equally high and long, with the lower angles somewhat obtuse. Tegmina fully developed, rarely abortive, with the mediastine area more or less extended, either narrow throughout or widened at the base, and sometimes including an adventitious vein. The scapular area is filled with oblique transverse veins and in the male is di-

Fig. 74.—*Orphula speciosa,* female. Original.

lated. The radial vein is composed of three principal branches; there is no intercalary vein. The ulnar vein is composed of two branches which sometimes unite again before the middle, the dividing vein is straight, and the plicate vein is free or united with the dividing. The wings are fully developed or rarely abortive, not fenestrated, rarely wanting. The posterior femora are frequently dull testaceous, rarely red. The sternum is rather broad, with the mesosternal lobes widely separated and the metasternal lobes distinct. The first abdominal segment is furnished with a closed tympanum. The anal segment is longitudinally sulcate with the supra-anal plate of the male obtusely triangular. The sub-genital plate of the male is recurved with the apex obtuse or acuminate. The valves of the ovipositor are short but exerted, and sometimes furnished with a lateral tooth.

THE SHORT-WINGED LOCUST.

(*Stenobothrus curtipennis* Harr.).

Olive-gray above, variegated with dark gray and black; legs and body yellow beneath; a broad black line extends from behind each eye on the side of the thorax; wing-covers, in the males, as long as the abdomen, in the female covering two-thirds of the abdomen; wings rather shorter than the wing-covers, transparent, and faintly tinged with yellow; hinder knees black; spines on the hind tibiæ tipped with black.

This is a very abundant locust, found most commonly among tall grasses of low and damp prairies and among blue grass growing thickly in shaded situations. In such places they can be found from early July till late in October. They are very easily distinguished from all other locusts by their short and narrow wings, the yellow color of the body beneath, and by the prominent yellowish hind legs with black

knees. Their noiseless life is but poor and short, nor does this insect leap well. McNeill says that, like its allies, it can scarcely be said to either fly or jump, but it suffers little or nothing in lacking these accomplishments, as its astonishing facility as a tumbler and contortionist generally discourage all but the most determined efforts for its capture. It is as prightly, wide-awake little "hopper," and an artful dodger.

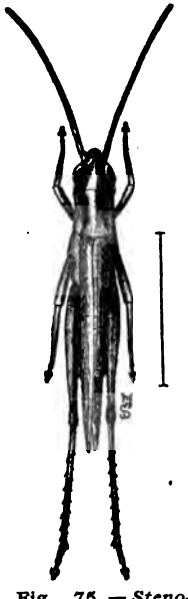


Fig. 75. — *Stenobothrus curtipennis*, male. Original.

"When about to stridulate these insects place themselves in a nearly horizontal position, with the head a little elevated. They then raise both hind legs together, the hind tibiæ bent back snugly against the femora during the movement and grate the thighs against the outer surface of the tegmina."

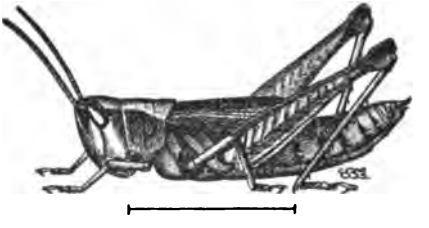


Fig. 76.—*Stenobothrus curtipennis*, female. Original.

Two forms occur, and several well-marked color varieties. The long-winged form was described as *longipennis*, Scudder; it is not as common in Minnesota as the short-winged one.

Total length male, 14 to 22 mm.; female, 12.4 to 23 mm.; of body, male, 13.5 mm. to 15.5 m.; of female, 15 to 24.5 mm.; of tegmina, male, 8.5 to 15 mm., female, 7 to 16.5 mm ; of hind femora, male, 10.5 to 11.8 mm., female, 11.5 to 14 mm.; of antennæ, male, 8.5 to 10.5 mm., female, 6.5 to 8 mm.

In Fig. 75 is shown a long-winged male, and in Fig. 76 a short-winged female.

GENUS *Gomphocerus* Thumb.

Similar to *Stenobothrus* except that the antennæ are furnished with a short depressed club at the apex, and (according to Brunner) the tympanum is partially open. Face almost vertical or sub-oblique. Antennæ long, multiarticulate, filiform for three-fourths of the distance from the base, the remaining joints forming a compressed expanded mass, not so large in the female as in the male, terminating in a point. Ocelli slightly visible. Eyes oval, slightly prominent. Pronotum short; its disk, flat, tricarinate; the lateral carinæ sinuous, curving inward or forming an entering angle near the middle; the posterior border rounded. Elytra and wings as long as or a little longer than the abdomen. Abdomen somewhat compressed; sub-anal plate of the male usually convex below, almost triangular. Prosternum unspined, smooth. Legs of medium length, and posterior femora of the usual form.

Gomphocerus clavatus Thomas.

This and *G. clepsydra* Scudder seem to be the same. This insect, easily distinguished from all members of the sub-family *Tryxalinæ* by its clavate antennæ, which are very prominent in the male, occurs everywhere in the prairies of Minnesota, from the Red River Valley in the north to the Pipestone quarries in the south; in the former region it was found in the adult stage as early as July 7. The description of *clavatus*, as given by Thomas, is as follows: Male.—Small size, antennæ clavate; elytra without spots. Vertex scarcely expanding in front of the eyes; the margins obtuse, elevated, meeting in front in an angle a little less than a right angle; apex obtuse; lateral foveolæ distinct, linear. Face oblique and slightly rounded; frontal costa very prominent, not sulcate at any point, gradually expanding below it and the entire face densely punctured; the lateral carinæ distinct; the sulcus that extends from the eye downward, sharp and distinct. Antennæ passing the thorax; the joints

in the middle portion somewhat distinct; the apex formed into a flattened club, very distinct; the cylindrical basal portion consists of about seventeen joints, usual form; the club of about seven joints, much shortened. Pronotum broadest and slightly swollen near the front, somewhat contracted posteriorly; the three carinæ about equally distinct, approximate, the lateral pair curve inward, making the nearest approach to each other a little in advance of the middle; sub-truncate in front, very obtusely rounded behind. Elytra and wings nearly as long as the abdomen; the nervules of the disk and lower field of the former scalariform. Sub-anal plate elongate, prow shaped, keeled, entire at the tip, which is sub-acute. Vertex and pectus densely punctured. Anterior tibiæ grooved externally, and broad toward the apex. Face and cheeks mottled with testaceous and brown (dried after immersion in alcohol); back of the head reddish-brown. Disk of the pronotum reddish-brown, with a brassy lustre; sides with the upper portion brown, the lower margin testaceous. Elytra pale-brownish, without spots. The abdominal segments marked on each side with a black spot, those on the basal segment largest, decreasing in size toward the apex, where they are almost obliterated. Ventral portion pale-yellow. Anterior legs carneous; posterior femora with the upper portion of the external face rufous, yellow beneath; internal face black near the base; tibiæ pale reddish-yellow, spines black.

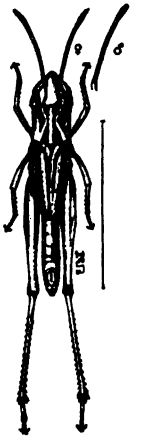


Fig. 76½.—*Gomphocerus clavatus.*

Measurements:—Length, male, 14 mm.; elytra, 9.25 mm.; posterior femora, 9.5 mm.; posterior tibiæ, 8 mm.

This species is illustrated in Fig. 76½.

GENUS *Eremnus* McNeill (1897).

Vertex somewhat declivent, broader than the frontal costa at the clypeus, sulcate, without a median carina, bounded by straight, sharp but slight carinæ, which meet at the front at an angle greater or less than a right angle. The lateral foveolæ are sub-quadrate, about twice as long as broad, very distinct and very apparent from above. The frontal costa is about half as wide at the vertex as at the clypeus, slightly sulcate with low broad carinæ along the sides. Seen from the side the face is moderately arcuate and moderately oblique. The antennæ are filiform, a little (female) or considerable (male) longer than the head and pronotum. The median carina of the pronotum is quite distinct and cut once behind the middle of the principal sulcus. The lateral carinæ are very strongly sinuate and the posterior margin of the metazone is roundly and very obtusely angulate. The lateral lobes of the pronotum are higher than long with the anterior and the posterior margins nearly straight and vertical. The mesosternal lobes are separated by a space several times as wide as long in both sexes. The metasternal lobes are separated by a space a little longer than wide in male and female. The tegmina and wings are well developed, not quite equaling or somewhat longer than the abdomen. The former have the scapular area transparent and filled with a single series of oblique cross-veins. The discoidal and the ulnar areas have each a false vein with a single row of cells on either side. The posterior femora have three usually well marked sub-triangular or irregular brown spots on the upper face. The posterior tibiæ are red or yellowish with the spurs on the inner side much elongated and very unequal. The ovipositor is very slightly exerted, only the extreme tip being visible.

Eremuus (*Aulocara*) *Scudderi* Bruner.

General color dull brown, in some specimens inclining to ferruginous, the tegmina usually very heavily and evenly

mottled with dark brown quadrate spots, sometimes only confined to the disk. Some specimens have a light testaceous band reaching from the vertex backwards across the middle of the occiput and pronotum to the tips of the tegmina. Posterior femora faintly marked with bands and spots; hind tibiæ bright coral red with a whitish basal annulus, the knee black; antennæ ferruginous, testaceous or lavender usually the latter in living specimens. Lower surface dirty yellowish-white.

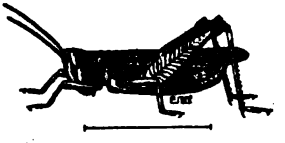


Fig. 77.—*Eremnus Scudderi.* Original.

Length of body, male 14.5 mm., female 20 mm.

This insect (Fig. 77), is not common, but is found among the grass in our prairies. It prefers sandy spots, upon which it will settle very closely, evidently protected in this manner by its similarity of color to such surroundings. It leaps vigorously for several times in succession, and without noise. It is found from middle of July to early October.

SUB-FAMILY.

(*Œdipodinæ.*)

This sub-family includes two tribes, the *Œdipodini* and *Eremobiini*, but as no insects belonging to the latter occur in Minnesota it is not necessary to give its distinguishing characters, which have already, in part, been given in the classification.

Œdipodinæ include genera in which the head is rounded at the union of the vertex and front, and in which the front is perpendicular or nearly so. The antennæ are linear or sub-linear, and usually inserted nearer the mouth than the middle of the eyes; sometimes they are inserted just in front of the eyes, which are small or of medium size, and really longer than that part of the cheeks below the eyes. In the typical forms the posterior lobe of the pronotum is longer

than the anterior one, and the median carina is frequently entirely or partially crested. As in the preceding sub-family the last spine of the outer row of the posterior tibiæ is wanting.

We possess in the United States not less than twenty-three genera only found here or in Mexico. The insects belonging here are mostly large and showy, often possessing bright-red, yellow, or even blue wings with black bands. Nearly all the bright-colored locusts found in the United States belong to this sub-family; most of them are very conspicuous objects in flight, when they show their color, which is at other times entirely hidden. This seems to indicate that these bright colors of the wings are by no means protective, but are probably of some value in the mating of the sexes. The color of the wings varies greatly in the same species, and we can in some cases find individuals that show all the shades of color from dull white through yellow and orange to vermillion red. This greater intensity of color is partly due to age, and, perhaps, to higher temperature. *Œdipodinæ* are also very noticeable on account of the rattling noise which the males of most species produce in flight. Even some females produce such sounds, but in a less degree. Stridulation is produced also when the insect is sitting on the ground, by rubbing the hind thighs against the wing-covers, the intercalary vein of which is in most cases toothed or roughened.

Genera of Œdipodini found in Minnesota.

A. Interspace between the metasternal foramina linear, or distinctly longer than broad in the male, narrower than the interspace between the mesosternal lobes in the females.

B. Tegmina subcoriaceous, densely or irregularly reticulate, only at the apex remotely areolate; wings brightly colored, red or yellow at base; none of the veins incrassate and no costal stigma.....*Arphia.*

BB. Nearly the whole apical half of the tegmina membranaceous; traversed by straight veinlets; wings with dilute coloring; the veins next the costal margin and frequently, in the male, the median vein incrassate; costa with a dusky stigma.

C. The intercalary vein of the tegmina running midway between the median and ulnar veins, only apically a little approximating the former; veins of the wings slightly or scarcely incrassate..... .....*Chortophaga.*

CC. The intercalary vein of the tegmina distinctly nearer the ulnar than the median vein, the veins next the costal margin and the median vein distinctly incrassate in the male; antennæ long, slender ....*Encoptolophus.*

AA. Interspace between the metasternal foramina rather broad, in the male quadrate, in the female transverse.

B. Principal sulcus more or less obsolete or delicate in the lateral lobes.

C. Smaller forms. Pronotum not rugose; wings sub-vitreous .....*Camnula.*

CC. Larger forms. Pronotum rugose; wings colored..... .....*Hippiscus.*

BB. Principal sulcus distinctly developed on the lateral lobes.

C. Pronotal carina entire or intersected by but one sulcus. Pronotum crested or carinate, but not excessively.

D. Wings conspicuously marked, but not banded..... .....*Dissosteira.*

DD. Wings with a fuscous arcuate median band.....*Spharagemon.*

CC. Pronotal carina twice intersected by transverse sulci.

D. Inferior margin of lateral lobes oblique, the posterior angle thereby acute or posteriorly produced.

E. Lateral canthi of the metazona terminating at the principal sulcus, or, if continued, it is a different course; tegmina fasciate or maculate.....*Mestobregma.*

EE. Lateral canthi of the metazona acute, passing in the same course beyond the principal sulcus; proximal half of the tegmina densely coriaceous.....*Psinidia.*

DD. Inferior margin of the lateral lobes horizontal, but anteriorly oblique, the posterior angle rounded-rectangulate.

F. Radiate veins of anal field of wings normal.....*Trimerotropis.*

FF. Radiate veins of anal field of wings distinctly incrassate.....*Circotettix.*

GENUS *Arphia* Stål. (1873).

Body compressed; pronotum granulated; median carina either notched or entire. Wing-covers subcoriaceous, densely and irregularly reticulate, only at the apex remotely areolate; the intercalary vein nearer the median than the ulnar vein; of one color, but sprinkled with minute black dots. Wings brightly colored, red or yellow at the base, margined externally with black; none of the veins incrassate and no costal stigma; ulnar area not noticeably dilated.

THE YELLOW-WINGED LOCUST.

(*Arphia sulphurea* Fab.).

Foveola of the vertex in the female slightly transverse, divided by a median carina, triangular in front, the margins raised and connecting in front, or approaching near to each other in a right angle; in the male somewhat elongate; the frontal costa prominent, more or less bisulcate above the

Fig. 79.—*Arphia sulphurea*, lateral view of pronotum.

ocellus, very slightly sulcate below it; face seen from the side decidedly arcuate. Pronotum (Fig. 79) scarcely constricted in the middle, but expanding slightly and regularly posteriorly; median carina prominent, sub-cristate or cristate, more or less arcuate on top; lateral carinae obsolete; surface somewhat roughened or rugulose; front margin obtuse-angled, slightly advanced upon the occiput; posterior margin right-angled or acute-angled. Elytra and wings passing the abdomen. Antennæ slender and filiform.

Uniform dusky brown, wing-covers rather paler than the pronotum, more or less distinctly spotted with dark brown. Wings deep yellow or sulphur-yellow next to the body, dusky at tip, the yellow portion bounded beyond the middle by a broad dusky-brown band, which curves and is prolonged on the hind margin, but does not reach the angle next to the extremity of the body; a very distinct ray running inward toward and nearly to the base near the front or

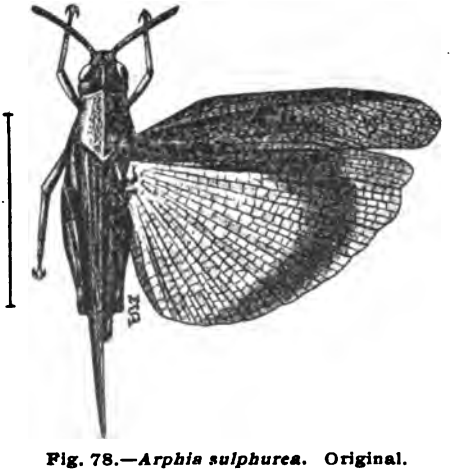


Fig. 78.—*Arphia sulphurea*. Original.

costal margin, leaving a narrow yellow strip along the costal margin. Posterior femora usually marked with alter-

nating bands of black and white, three of each; posterior tibiæ dusky, black or blue-black, with a pale ring near the knee; spines black. The male insect is illustrated in Fig. 78.

Measurements:—Male: Total length, 23-26.5 mm.; of body, 17-19 mm.; of tegmina, 17.5-20 mm.; of hind femora, 11-12.5 mm.; of antennæ, 6-7.5 mm. Female: Total length, 28-30 mm.; of body, 26-28 mm.; of tegmina, 20.5-23 mm.; of hind femora, 13.5-15.2 mm.; of antennæ, 6-7.5 mm.

This is a very common species in all parts of the state visited by the writer at the proper time. As soon as the snow disappears and the ground becomes warm enough to start vegetation, this insect becomes active, and may be found as larva, pupa and adult. The latter, when disturbed, fly readily, and to some distance, making a loud clattering sound. They disappear about the middle of July. The colors of the wings vary greatly; in some the brilliant yellow is replaced by a very light yellow. This is our most common form near St. Anthony Park.

Arphia xanthoptera Burm.

Thorax, generally, though not always, darker than in *A. sulphurea;* sometimes with two yellow dots on the middle of the sides of the pronotum, one above the other, and the front and hind margins dotted with olive; but these markings are not uniform. The dark ray of the wings near the front margin, not more than half as long as in *sulphurea*, extending but one-third the distance to the base; this is remarkably uniform. Posterior femora generally with two oblique dull yellowish bands on the exterior face, and also a paler and more distinct ring near the apex. The yellow of the wings is usually much deeper and more inclined to a saffron color. It differs also in being larger, in some cases the length of the female from tip to tip of wings being two inches. The foveola of the ver-

Fig. 80.—*Arphia xanthoptera*, lateral view of prothorax.

tex is usually open in front, its margins continuous with the margins of the frontal costa; the median carina of the pronotum is higher and more distinctly arched, the angle of the anterior more distinct, and of the posterior margin more acute.

Measurements.—Male: Total length, 30-34 mm.; of body, 21-25 mm.; of tegmina, 22.5-27 mm.; of hind femora, 14.5-17.5 mm.; of antennæ, 10-11 mm. Female: Total length, 34.5-40 mm.; of body, 28-32 mm.; of tegmina, 26.5-30 mm.; of hind femora, 17-18.5 mm.; of antennæ, 9-11.5 mm.

This species is not common, at least has not been taken in as large numbers as the other species of *Arphia*. It varies very much in color, some specimens being almost black, others bright reddish or yellowish-brown; in the east it is entirely yellow-winged, in the central states frequently orange-winged. It is found in the same localities, among grass and low bushes in barren fields or pastures on dry soil, as the very common *sulphurea*, but is found much later in the season, not before the first of August. According to Morse the two specimens *xanthoptera* and *sulphurea* can be readily separated. The hind process of pronotum of the former is acute-angled in dorsal view, its sides concave. Carina of pronotum in a side view crest-like, high, arched and compressed, Fig. 80. Dusky band of wing with sub-frontal shoot usually extending one-fourth to one-third the distance across disk to base of wing. In *sulphurea* the hind process of pronotum is about right-angled in the male, or a little obtuse in the female; carina rather low. Dusky band of wing with sub-frontal shoot usually extending two-thirds of the distance to base of wing.

Arphia carinata Scudder.

Head blackish, profusely streaked and spotted with dull bluish-white; frontal carinæ and upper border of clypeus edged with whitish; palpi blackish, the joints tipped with

luteous. Pronotum (Fig. 80), dull, dark, brownish-fuscous, with a short pale streak behind the lower edge of the eye; hind edge of pronotum forming less than a right angle; median carina very prominent, whole, sharp, rounded. Basal third of tegmina dark brownish fuscous; beyond ash-gray, profusely and rather regularly sprinkled with small brownish spots; basal half of wings pale dull orange, bordered by a broad blackish fuscous band, occupying the rest of the wing, excepting the apex, and encroaching on the orange near the costal margin, as in *xanthoptera;* apex semi-pellucid, a little fuliginous, darker at the very tip. Hind femora dull, dirty, hoary without, black with three transverse white bands within, the tibiæ blackish-brown with black spines and a broad pale band near the base.

Length 30 mm.

This species occurs with the two others already described but is by no means common. It can be readily distinguished by the facial costa, which is acuminate towards the vertex in *sulphurea*, while in *carinata* the sides of the facial costa are nearly parallel from the median ocellus to the vertex. The carina of the pronotum of the latter is very high and strongly arched, while in the former it is but little elevated and nearly straight. This insect flies late in August.

Arphia tenebrosa Scudder.

Closely allied to *sulphurea*. Upper part of the head regularly convex; central foveola of the vertex sub-elongate, with a slender median carina, and a transverse sulcus across the hinder portion, generally truncate and closed in front; upper part of the frontal coxa sub-tricarinate; rest flat, arcuate below as seen from the side. Antennæ slightly flattened and somewhat enlarged toward the tip. Median carina of the pronotum distinct, somewhat prominent but less so than the *sulphurea*, nearly straight on top, cut near the middle by the transverse sulcus, but not notched; an-

terior margin of the pronotum obtusely rounded, apical angle about a right angle; lateral carinæ sub-distinct; disk of the posterior lobe nearly flat. Wing-covers and wings longer than the body.

Nearly uniform dark fuscous, often ash-color sprinkled over with fuscous dots, males sometimes almost black; face paler, dotted over with black points; mouth whitish

Fig. 81.—*Arphia tenebrosa*, dark variety. Original.

or pale; outer joints of the palpi usually whitish or pale; pronotum above is sometimes paler, almost yellowish-white, or of a dull dirty-yellow or partially of this color, usually dusky or brown. Elytra with paler spots, but varying in depth, sometimes almost uniform brown. Wings with the broad basal portion bright red, or orange-yellow; a broad black band around the outer margin, with a dark sub-costal ray extending towards the base; the extreme tip transparent, more or less clouded or spotted with fuscous.

Posterior femora usually crossed externally by three ill-defined pale bands; posterior tibiæ black at the knee, below with a pale ring, middle portion varying from bluish-green to black. Two forms of this insect are shown; Fig. 81 represents a dark, and Fig. 82 a light-colored, male.

Length about that of *xanthoptera*.

This is one of the most common of our locusts with bright colored wings. A few are found early in the season

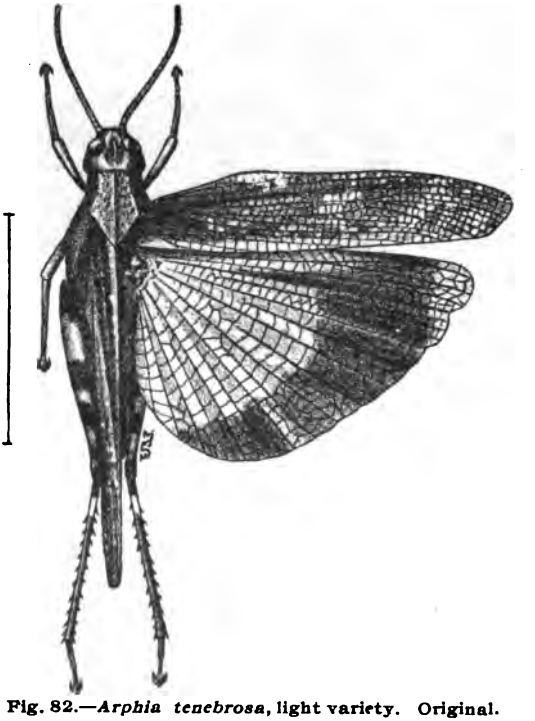


Fig. 82.—*Arphia tenebrosa*, light variety. Original.

(May 16), but they become very abundant in July, and are at that time very active. They fly with a clattering sound; the males have also the habit of remaining in one spot in the air, moving the wings so rapidly at that time that they can hardly be seen. On Sept. 13 the writer found a female of this kind mating with a male of the still more common Carolina Locust (*Dissosteira carolina L.*).

Arphia arcta Scudder.

Head grayish-brown above, yellowish elsewhere, the median carina of vertex broken at the posterior limit of the fastigium by the deeply impressed, arcuate, transverse furrow, which marks the same, extending through the frontal costa nearly to the ocellus, expanding and forming an oval loop at the extremity; lateral foveolæ strongly depressed, narrowing anteriorly. Pronotum grayish-brown, the upper surface unusually flat for an *Arphia*, rugulose, the median carina but little elevated, not laterally pinched in the middle, regularly, though but slightly, diminishing in height posteriorly. Tegmina profusely sprinkled with very small grayish-fuscous spots, less abundant apically, where it is pellucid. Wings yellow at the base, pellucid to an unusual extent at the tip (nearly one-third of the ante-anal field is included in the pellucid area), making the transverse dusky band narrower than in any other species of *Arphia*; the radial shoot towards the base is, however, unusually broad and long, equaling at its origin the entire breadth of that part of the wing, and scarcely stopping short of the base. Hind femora brownish-yellow externally, with two broad, a little oblique, dusky transverse, bands; hind tibiæ pale yellow, with a broad fuscous cloud at the tip and just before the middle.

Length of body, 21 mm.; of antennæ, 5.5 mm.; of tegmina, 22.5 mm.; of hind femora, 11.5 mm.

Only two individuals of this interesting insect, first described from the vicinity of Denver, Colorado, were captured in St. Anthony Park, and no others have been seen.

Still another species occurs in the Park, but seems to be undescribed.

GENUS *Chortophaga* Saussure (1884).

Body compressed, somewhat slim, pundate or fine wrinkled, greenish, sub-glabrous, slightly pubescent. Legs remote, with scattered hairs on their surface. Antennæ rather short, and slightly flattened. Pronotum acute,

angled behind. Wing-covers narrow; costal half green, sutural half brownish. Wings with dilute coloring, nebulous; costa with a dusky stigma; ulnar area dilated. The intercalary vein of the tegmina running midway between the median and ulnar veins, only apically a little approximating the former; veins of the wings slightly or scarcely incrassate. In coloration, dichromatism, form of head and character of haunts it is intermediate between the *Œdipodinæ* and the *Tryxalinæ*, with which it was formerly classed.

THE GREEN-STRIPED LOCUST.

(*Chortophaga viridifasciata* DeGeer).

This common locust is exceedingly variable, and a number of varieties occur, which shade into each other. Two

Fig. 83.—*Chortophaga viridifasciata*, form *virginiana*, male. Original.

well marked varieties are found, the green form (*virginiana* Fab.), and the brown form (*infuscata* Harris). This dichro-

matism is largely, but not entirely, characteristic of sex; most of the females being green, of the males brown.

The green variety is the typical one; wing-covers with a broad green stripe on the outer margin, extending from the base beyond the middle, and including two small dusky spots on the edge, the remainder dusky, but semi-transparent at the end; wings transparent, very pale, greenish-yellow next to the body, with a large dusky cloud near the middle of the hind margin, and a black line on the front margin. Antennæ, fore and middle legs reddish; hind femora green, with two black spots in the furrow beneath. This form is the larger one. Both sexes are illustrated in Figs. 83 and 84.

The dusky brown variety has the wing-covers faintly spotted with brown; wings transparent, pale greenish-

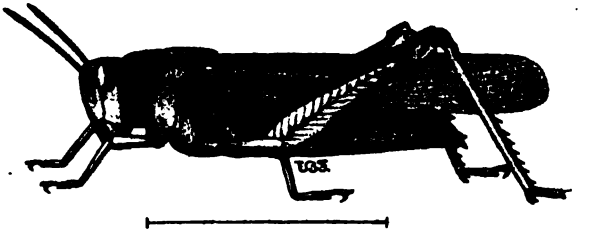


Fig. 84.—*Chortophaga viridifasciata*, form *virginiana*, female. Original

yellow next to the body, with a large dusky cloud near the middle of the hind margin; and a black line on the front margin; hind femora pale, with two large black spots on the inside; hind tibiæ brown, with darker spines, and a broad whitish ring below the knees. The hind tibiæ differ much in color in different specimens, being variously tinted with brown, blue, pink or purple, without regard to sex. Many intergrades occur, in which the head and pronotum are of a reddish velvety brown. This form is shown in Fig. 85.

Length of male, 25 mm.; of female, 30 mm.

This is a very common locust in our state, appearing very early in spring and continuing throughout the summer. It hibernates, and larvæ and pupæ are occasionally observed during a warm spell in winter. Early in spring (April 18), or as soon as the ground becomes warm, winged forms

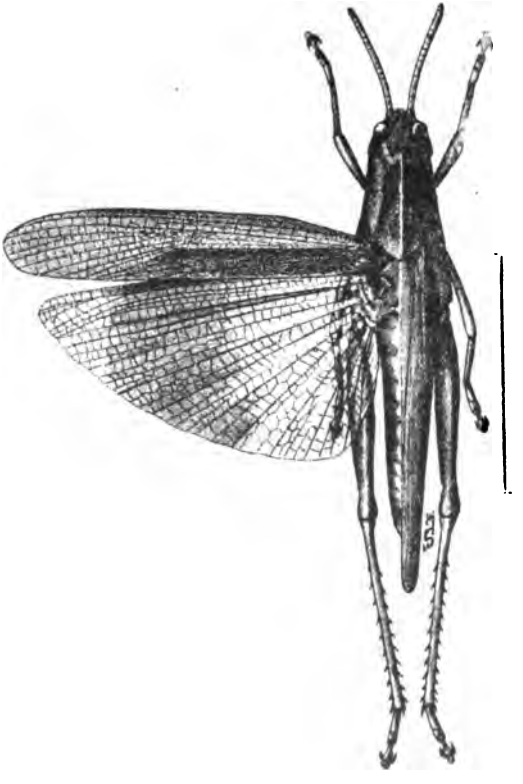


Fig. 85.—*Chortophaga viridifasciata*, form *infuscata*, Original.

appear, and these can readily be detected by their sharp clicking notes when flying. *Arphia sulphurea* and this species are the first locusts observed in spring, and usually both are found in the same localities, starting the chorus of grasshoppers, locusts and crickets that becomes so general later in the season. While taking wing readily its flight is

but short and it is not difficult to capture. The male flies in a circling course, and usually stridulates, producing a fine, sharp crepitation; the female flies farther and more directly. We have but a single brood in our state; the eggs hatch late in summer and the young do not mature until the following spring. The form *infuscata* is always more common than the green one.

GENUS *Encoptolophus* Scudder (1875).

Head but little swollen above, front vertical above-roundly sloping below, a little constricted above the antennæ; eyes separated by about their own width, moderately large, somewhat elliptical; antennæ rather short and flattened; top of pronotum nearly flat, the median carina abrupt, but not greatly elevated, cut into halves by a distinct though slight notch; lateral carinæ distinct but broken, very slightly curved; hind margin of pronotum forming a right angle; wing-covers reaching but little beyond the end of the abdomen. The intercalary vein of the tegmina distinctly nearer the ulnar than the median vein; the veins next the costal margin and the median vein distinctly incrassate in the male.

THE CLOUDED LOCUST.

Encoptolophus sordidus Burmeister.

Dusky brown; wing-covers pale, clouded and spotted in such a manner that two transparent spots or fasciæ are distinctly marked; wings transparent, faintly yellowish at base, dusky at tip, with a dark narrow edge on the front margin; hind femora brown, with the three black bands separated by four light-brown spaces; hind tibiæ brownish-black, with a white ring below the knees. Antennæ pale at base, fuscous at the apex.

Measurements:—Male: Total length, 21-28.5 mm.; of body, 19-21.5 mm.; of tegmina, 15-19.5 mm.; of hind femora, 11-12 mm.; of antennæ, 8-9 mm. Female: Total

length, 28-32.5 mm.; of body, 24-35 mm.; of tegmina, 20.5-24 mm.; of hind femora, 14-15.5 mm.; of antennæ, 8-9 mm.

This is a fairly common locust, which is found from the middle of August till frost, or late in October. Like the males of allied species the male of this species always makes a sharp crackling noise when flying, which it does with amazing rapidity. It is especially common in the western part of our state. Its color, which is rather constant, varying from dull rusty, yellowish, or smoky brown, always protects the insect by its resemblance to the soil. It delights to live in old stubble fields. Fig. 86 shows a male.

Fig. 86.—*Encoptolophus sordidus*. Original.

GENUS *Camnula* Stål. (1873).

Head compressed; antennæ medium, a little stouter in the male; hind femora with an acute margin slightly crested; eyes small, rather prominent, rounded kidney-shaped. Pronotum not rugose, nearly level above with median and lateral carinæ. Wings subvitreous.

In the markings of tegmina form and color *C. pellucida* looks like a diminutive *Hippiscus*, to which *Camnula* is not distantly related.

Camnula pellucida Scudder.

Ash brown; face reddish-brown; antennæ yellowish at base, dark brown toward tip; a triangular black spot behind the eye, the apex touching it; a quadrate transverse black spot on the anterior upper portion of the sides of the pronotum; pronotum above sometimes with a dark band down the middle; wing-covers with the basal half dark brown, with small yellowish spots and transverse streaks, especially on front border; apical half clear, with dark

brown rounded spots prevalent along the middle, decreasing in size toward the tip; when closed, the upper surface is dark brown, with a rather broad yellowish line along each angle on the upper surface; wings pellucid, with black nervules; legs dark brown, the hind femora reddish or yellowish-brown, with two or three rather broad, diagonal, dark brown streaks, dark brown at the apex; hind tibiæ yellowish-brown, reddish toward the tip, with a narrow, generally faint, annulation of dark brown at the base; spines tipped with black.

Fig. 87.—*Camnula pellucida*, female. Original.

This insect is sometimes exceedingly common, and becomes a destructive species. In this respect it is almost as bad as *Melanoplus atlanis;* both have appeared repeatedly together, and have caused great loss. The former, however, preferred higher land, the latter lower or more moist soil. This species varies considerably in size and tegminal markings—some tegmina are almost without marks—but is not likely to be confused with any other species found in Minnesota.

Measurements:—Male: Total length, 20.5-24.5 mm.; of body, 17-21 mm.; of tegmina, 15.5-18.5 mm.; of hind femora, 9.5-12.5 mm.; of antennæ, 7-9 mm. Female: Total length, 22-30 mm.; of body, 21-28 mm.; of tegmina, 19-23.5 mm.; of hind femora, 11-14.7 mm.; of antennæ, 6-8.5 mm.

This destructive insect, illustrated in Figs. 87 and 88, is not always found in our state; it belongs to the migratory

species, and if occurring in the state it is found in its winged condition as early as July 1, and it does not disappear until the middle of September. Its flight is silent or but slightly

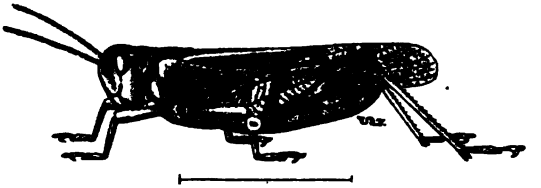


Fig. 88.—*Camnula pellucida*, male. Original.

rustling, usually low, short and direct. The illustration (Fig. 1) shows this insect and its eggs. Its life-history is given elsewhere.

GENUS *Hippiscus* Saussure (1861).

Large or medium sized, robust, glabrous. Top of the head with a small central ridge; pronotum with a granular surface, truncate in front, acute-angled behind, compressed centrally on the sides, and above on each side of the median carina; this last with one notch; lateral carinæ prominent only in the middle. Wing-covers extending considerably beyond the end of the abdomen.

This is a large genus, and has been subdivided into a number of sub-genera by Scudder and Saussure.

Hippiscus rugosus Scudder.

Head and thorax brown; two yellowish bands run from behind the eye backward and inward, nearly or quite meeting one another a little in advance of the middle of the pronotum, where they diverge and strike the hinder edge of the pronotum at the outer angles; there are two yellowish spots, one below the other, on the sides of the pronotum; wing-covers marked with large dark blotches, generally occupying the larger portion of the wing; the tip of the wing-cover pellucid, nearly free from spots; wings with the basal color pale yellowish or red, and the apical portion dusky.

Last, forked branch of the discoidal vein of the hind wings usually arising about three-fifths the distance from the base to the apex of the wing, and in the male usually well within the limits of the transverse fuscous belt; closed tegmina of male surpassing the abdomen by at least one-fourth their length. The very broad posterior femora crossed externally and internally by three black bands; posterior tibiæ reddish yellow, with a broad, pale ring near the base. This species is more slender than the others found in Minnesota.

Size about the same as *tuberculatus*.

This species is not common, at least but few have been collected, both with yellow or red wings. They prefer sandy spots, and fly as early as Aug. 14. It can readily be distinguished from *tuberculatus* by the form of the head and pronotum. The wings are usually yellow, often pale yellowish-white, sometimes orange or even red.

Hippiscus tigrinus Scudder.

Dark brownish fuscous, of robust form and medium size. Head narrowed above and rugulose; pronotum expanding considerably on the metazona, which is centrally a little tumid, the rugosities of the latter, which are considerable, ranged more or less distinctly into series parallel to the sides of the process; median carina sub-obsolete or at least depressed between the sucli, distinctly arched on the metazona; lateral canthi distinct and sharp in the middle of the pronotum, a faint rather broad ashen band next their inner side. Tegmina ashen gray, brownish at base, vitreous on apical third or more, the transverse bars dark brownish fuscous, mostly crossing the wing, those of apical half not at all rounded, with rare exceptions with ill defined irregular margins, and extending though fainter to the tip of the wing; sutural line testaceous. Wings very pale, citron-color at base, pellucid at tip, occasionally with one or two fuliginous cellular spots at tip, the veins and cross-veins blackish on apical portion, yellow on basal, with a broad,

sub-equal, arcuate, dark, fusco-fuliginous, median, scarcely tapering band, leaving four or five lobes free, separated by a yellow line from the humeral vitta which extends from very nearly as far out to the base of the wing, the costal margin fusco-testaceous. Hind femora externally brownish fuscous with only obscure, if any, darker very oblique bars, dirty

Fig. 92.—*Hippiscus tigrinus*, female. Original.

clay-yellow below, the under surface, like the tibiæ and tarsi, luteous, the spines black tipped.

Length 37 mm.

Only two specimens found. This species is illustrated in Fig. 92. It seems to be a southern species. All the species of this large genus of locusts resemble each other so closely when in the field, or when flying, that only very careful collecting in all parts of the state will give a clear idea of the

species really found in it. Very little has been done as yet to ascertain how many species have their home with us.

Hippiscus tuberculatus Pal. de Beauv.

This is our common coral-winged locust, found so commonly in early spring in all parts of the state. The early stages, from the half grown larvae to the pupae, pass the winter under the shelter of leaves and grass; they mature

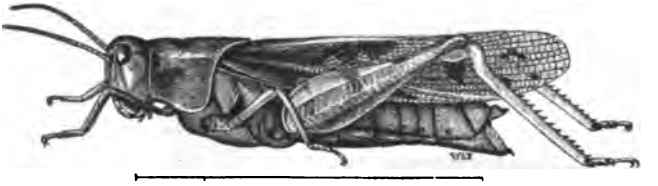


Fig. 89.—*Hippiscus tuberculatus*, female. Original.

very early in the spring, and are found flying about in the warm sunlight as early as the last week in April. Although found everywhere in Minnesota they still appear to be quite local and prefer certain localities, where they can always be found at the proper time. It is this insect that is mentioned as *H. phœnicopterus* in the reports about the

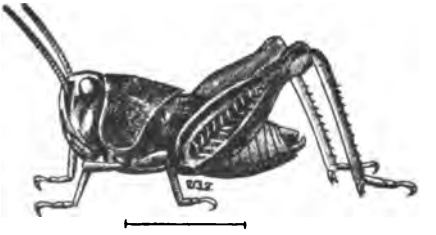


Fig. 91.—*Hippiscus tuberculatus*, young. Original.

Rocky-Mountain Locust; it is not uncommonly called the "King Grasshopper," as some people thought it to be the leader of the large and devasting armies of the above locust. The three illustrations, (Figs. 89, 90, 91,) show the adult insects and a young one.

There is considerable variety in this species, so much so that several varieties might be formed. Scudder's description of living females taken in Massachusetts fit our insect thoroughly well: Prevailing color a light ashy plumbeous, slightly darker above, specked with dark plumbeus, tinged slightly beneath with reddish. Head uniform; mouth-parts

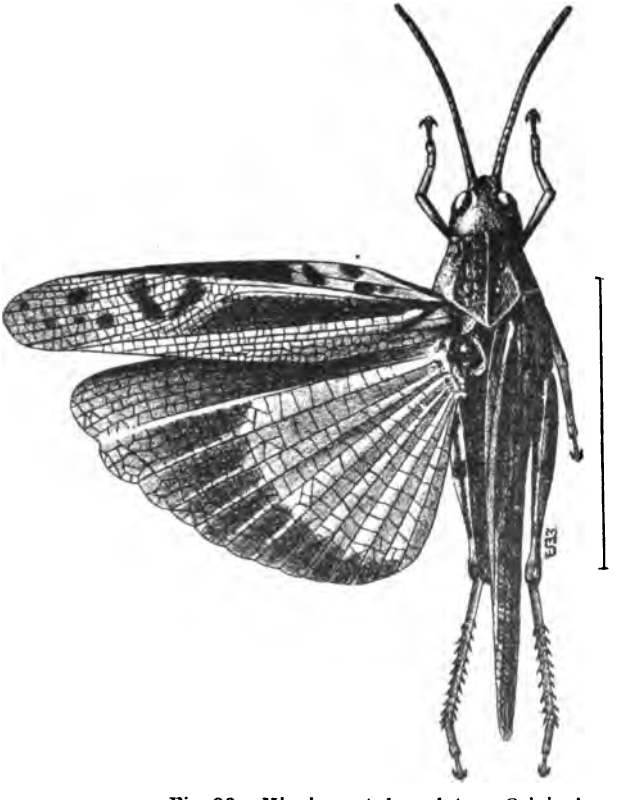


Fig. 90.—*Hippiscus tuberculatus*. Original.

uniform and tinted like under surface of body. Eyes dark brown, speckled with yellowish and with a narrow slightly curved transverse median streak of yellowish-brown, turning upwards posteriorly. Antennæ dirty yellowish at the base, beyond of the color of the head. Pronotum with a longitudinal dark brown streak with indistinct edges along

the middle of the lateral lobes, and from the middle of this a descending vertical streak scarcely paler than the ground; posterior edge of pronotum a yellowish-brown of the color of boxwood. Tegmina of the body color or blotched with fuscous and black, and with the axillary fold yellowish brown. Wings coral-red at base, the arcuate band fuscous deepening to black, the humeral line pale yellow and the apex nearly hyaline. Legs of the body color, the inside of the hind femora having the basal half a prussian blue, the distal half very dull lemon yellow with a transverse streak of deep blue at one third the distance from the middle; hind tibiæ dull lemon-yellow, hind tarsi tinged with reddish. Abdomen above tinged on the first three segments with reddish brown, especially toward apex; ovipositor of the color of the body when not black. Metazona without lateral oblique rugæ.

Total length of male, 32-38 mm., of female, 39-43 mm.; of body, male, 25-28 mm., of female, 36-44 mm.; of tegmina, male, 24-30 mm., of female, 30-32 mm.; of hind femora, male, 14-16 mm., female, 18.5-20.5 mm.; of antennæ, male, 10.5-12 mm., female, 11.5-13.5 mm.

Yellow-winged specimens of this species are very rare. Sometimes the head, pronotum and hind femora are greenish. The young insects, one of which is shown in the illustration (Fig. 91), can be found late in August; they are curious little depressed, toad-like objects, of a purplish leaden color. Though very conspicuous objects in flight, the adult insects are quite alert and active, so that they are not easily captured. If flushed the male flies to a considerable distance; the female is much less active, and is more difficult to flush more than once, as it tries to escape rather by hiding than by flying. The stridulation of the male is a rapid rattle, louder but similar to that of *Arphia sulphurea*, which flies at the same time and in similar localities, bushy pastures and untilled or elevated land of light soil.

Hippiscus Haldemanii Scudder.

Granules on dorsum of metazona by their confluence distinctly following lines forming oblique rugæ parallel to the hind margin; lateral canthi of pronotum as distinct and sharp on the hinder part of the prozona as on the front part of the metazona.

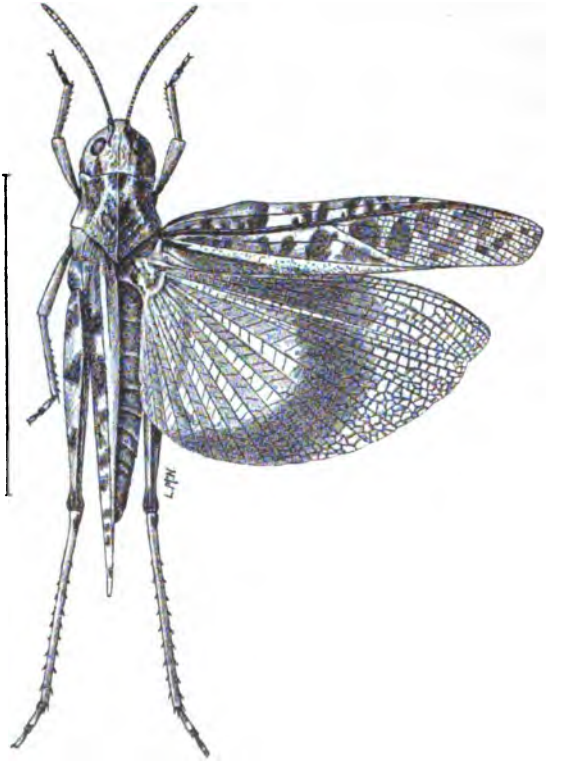


Fig. 93.—*Hippiscus Haldemanii*, female. Original.

This is a medium sized member of this genus, illustrated in Fig. 93, with yellow wings and pale red tibiæ of hind legs. It has been reported from the Red River Valley, but no specimens have been secured by the writer.

Hippiscus variegatus Scudder.

Markings of tegmina distinctly pantherine, marginal field with numerous small blotches; wings of male fully twice as long as broad; hind margin of prothorax rectangulate. Basal color of wings varying from a pallid tint through pale lemon yellow to saffron and coral-red. Hind femora bright yellow within, thrice heavily banded trans-

Fig. 94.—*Hippiscus variegatus*, male. Original.

versely with black; dull clay yellow without, very obliquely banded with blackish or fuscous; hind tibiæ yellow with an orange tinge sometimes infuscated a little just beyond a broad clear basal belt; spines black tipped.

Length of body, male, 28 mm., female, 37 mm.; of tegmina, male, 28 mm., female, 35.5 mm.

This species is uncommon in Minnesota, and but a very few specimens have been seen or captured. It is illustrated in Fig. 94.

GENUS *Dissosteira* Scudder (1876).

Head prominent, vertex elevated and tumid; antennæ of the male not thickened before, nor tapering at the tip; posterior lobe of the pronotum somewhat enlarged, median carina much elevated, deeply notched near the middle, the posterior lobe much arched. Insects of large size and prominent colors.

THE CAROLINA LOCUST.

(*Dissosteira carolina* Linn.).

This is a very common locust, and is found from early July until late in autumn. Few persons do not know its peculiar actions during the warmer portions of the day, when the males fly two to six feet in the air, and there remain almost stationary, producing a peculiar rattling, or rather rustling sound. This seems to be their love song. After pairing, which takes place early in August, and all through that month and September, the female deposits her eggs at the bottom of a cylindrical hole; the eggs do not hatch until spring. The female can greatly extend her abdomen, so that eggs can be found as deep as nearly two inches below the surface. The insect prefers warm and sandy situations, and is most commonly found upon sandy spots. Its upper wings vary greatly in color, but possess always that one which harmonizes best with the color of the sand upon which the insect is found, hence all shades of light or dark yellowish, brown, reddish, and even blackish can be seen by observing the insect upon sands possessing that shade of color. The usual color of this locust is a pale yellowish-brown, with small dusky spots, wings black, with a broad yellow hind margin, which is covered with dusky spots at the tip. From the prevailing brown tints of its coloring it has in some localities received the name of "Quaker." Though quite variable in appearance it is easily recognized by its black wings with pale border, which

varies from dull-white to yellowish-buff. The most striking variation, however, is the ground color of the body, which varies in specimens from the same locality from light yellow to dark fuscous or even bright reddish-brown. The tegmina are sometimes markedly trifasciate, sometimes evenly maculate or almost unspotted. Possessing large wings its flight is powerful and erratic; it is very alert and well able to take care of itself, and on warm days it is rather difficult to secure. The insect is shown in Fig. 95.

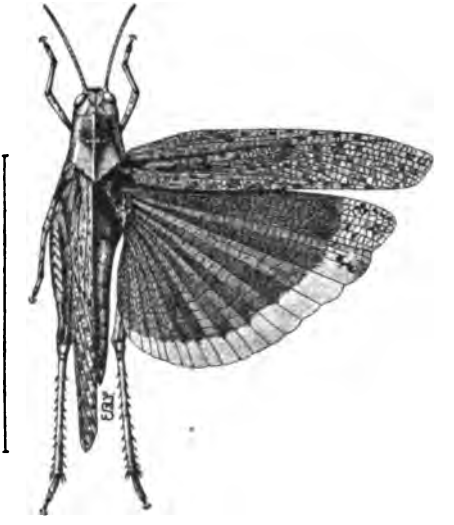


Fig. 95.—*Dissosteira carolina*, female. Original.

Measurements:—Male: Total length, 34.5-42 mm.; female, 43.5-53 mm.; of body, male, 24-28 mm.; female, 33-42 mm.; of tegmina, male, 28-33.5 mm.; female, 36-43 mm.; of hind femora, male, 12.6-14 mm., female, 15.5-20.5 mm.; of antennæ, male, 9.5-11 mm., female, 11.5-13 mm.

GENUS *Spharagemon* Scudder (1875).

Saussure united this genus with *Dissosteira*, but later studies by Scudder, Morse and others clearly show that it is a good genus, well separated from the former, as may be

seen by consulting the table of genera of the *Œdipodini*. Morse adds to the description of this genus by Scudder that the median carina of the pronotum is divided by the principal sulcus into two parts, the front portion a little shorter. The eyes of our species are of moderate size, and rather prominent in the males.

Spharagemon collare. Scudder.

Central foveola of the vertex rather broader than long in the female, in the male slightly elongate; frontal costa flat or convex above the ocellus, with a shallow sulcus below; sides nearly parallel. Median carina of the pronotum prominent, sub-cristate, with a very narrow but deep oblique notch a little in advance of the middle; the top slightly arcuate; lateral carinæ indistinct; sides of the disk ascending. Tegmina and wings pass the abdomen about one-third their length. Dark reddish-brown. Lower half of head and a broad band along the posterior edge of the pronotum a clay-yellow, sprinkled with a few fuscous dots. Tegmina mottled somewhat uniformly with fuscous blotches and dots, which form three irregular bands, one at the base, which is broad, the middle one narrowest, the apical one sometimes lost in the nearly equal mottling of the tip. Wings pale yellow at base; a broad median black band occupying the middle third, crossing the wing at right angles, decreasing along the posterior margin, around which it curves to the anal angle, throwing out a short, blunt, subfrontal spur about one-third the distance to the base; apical portion transparent, nerves dusky, and tip clouded or with dusky spots. Hind femora clay-yellow, with two bands and apex fuscous externally and black internally; hind tibiæ reddish. Antennæ fuscous at the apex.

According to Prof. Morse the species described as *collare*, *Wyomingianum*, and *Scudderi* approach each other so closely that it is almost impossible to definitely limit them. Typical specimens of these forms can be readily distinguished,

while others cannot be referred to either of them with certainty, and for this reason he thinks it best to regard them as races of one composite species.

RACE *Collare* Scudder.

Only a single specimen of this race has been found in Minnesota, which seems to indicate that it is not common,

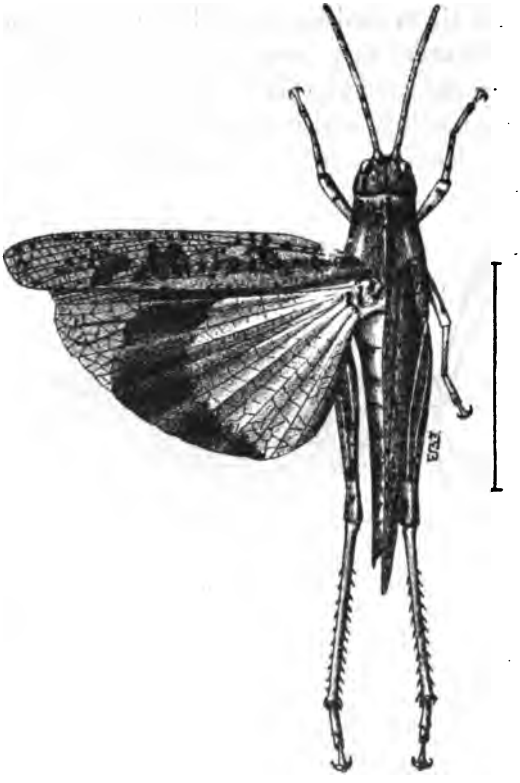


Fig. 96.—*Spharagemon collare*, race *Scudderi*, female. Original.

though it is a wide-spread form in the central part of the country. It differs greatly in color and size. The "collared" type of coloration is not common. The hind femora sometimes have the proximal two fuscous bands slightly connected internally, but never to such an extent or depth of tint as in the race *Scudderi*.

Measurements:—Length, 26.5-33 mm.; of tegmina, 21.5-26 mm.; of hind femora, 11.5-14.5 mm.; of antennæ, 12 mm.

RACE *Scudderi* Morse.

This race is very common upon sandy spots near the Mississippi River, and large numbers were taken on Gray Cloud Island. The specimens were named by Prof. Bruner ***balteatum;*** a male mailed to Prof. Morse was pronounced: race *Wyomingianum* Thos. (nearly typical), while a female, caught at the same time and place was pronounced as being probably the same, but in size, form of head, etc., closely approaching race *Scudderi;* in fact being nearer *Scudderi* than *Wyomingianum*.

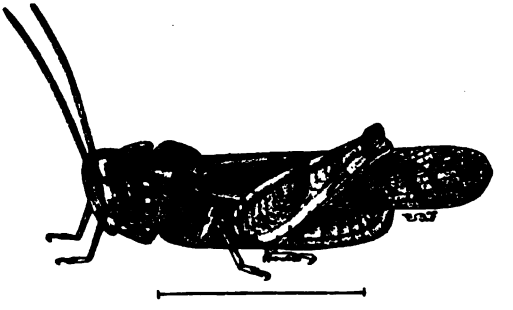


Fig. 97.—*Spharagemon collare*, race *Scudderi*, male. Original.

This locust is quite common in certain rather well defined localities. Nearly all specimens captured were found upon sandy spots near our rivers and lakes. Here they can be found as early as the 25th of June. Like the Carolina Locust described before they also remain flying stationary a few feet above the ground and likewise produce the dry rustling sound, which has something to do with their courtship. Frequently both species fly at the same time and in the same vicinity, and both are equally well protected by their colors if resting upon the sand. They delight to bask in this hot sand, yet are very vigilant and difficult to capture excepting with a net. When resting upon the sand, which always con-

tains small bits of bark brought down by the overflowing river, it is almost impossible to detect this insect, which, moreover, seems to be able to understand how to select a spot that exactly matches with its own color. Both sexes are shown in Figs. 96 and 97.

BARREN-GROUND LOCUST.

Spharagemon bolli Scudder.

This locust is very variable in color, but is usually brownish fuscous, the face with a grayish cinereous (in the male) or yellowish cinereous (in the female) tinge, distinctly marked with blackish dots, the pits dusky or blackish; antennæ brownish-yellow on the basal half, infuscated beyond, the whole more or less annulate with dusky yellow and blackish in the male. Wing-covers flecked throughout with minute blackish spots. Wings light greenish-yellow at the base with a broad median arcuate band, blackish in color, sending out a broad short shoot towards the base next the upper border. Beyond, the wing is at first hyaline, with broad blackish, fuliginous veins, while the extreme tip is more or less covered with black. Hind femora dull brownish; the basal two-fifths of the hind tibiæ blackish, with a broad whitish annulus beyond, coral-red. Crest of pronotum very high, that of the posterior lobe independently arched, much more elevated in front than behind.

Fig. 98.—*Spharagemon bolli*, male. Original.

Measurements.—Male: Length of body, 20-22 mm.; of tegmina, 22-25 mm.; posterior femora, 12.5-13.5 mm.

Female: Length of body, 27-33 mm.; of tegmina, 23-28 mm.; posterior femora, 12.5-17 mm.

This species has been found in many parts of the state, but most frequently along the sandy shores of rivers and lakes, and on the tops of high and sandy hills. It is shown in Fig. 98.

GENUS *Mestobregma* Scudder (1875).

Head large; face horizontal; vertex tumid, but not so elevated as in *Psinidia*, broad between the eyes, the fastigium quadrate, depressed, with very high and abrupt lateral and frontal carinæ, which form the continuation of the sides of the equal, completely sulcate frontal costa; lateral foveolæ small, depressed, rudely semi-circular, the ocelli situated beneath their outer extremity; eyes small, moderately prominent, but little longer and not so broad as the space between them; antennæ (female) about as long as the hind femora. Pronotum posteriorly as broad as the head, somewhat constricted in the middle, the hind lobe scarcely longer than the front, the posterior border rectangular; median carina moderately conspicuous, slightly higher on the front than on the hind lobe, twice deeply cleft, the transverse sulcations extending into the lateral lobes; lateral carinæ of posterior lobe prominent; surface of hind lobe nearly flat, pretty smooth; front lobe with a few oblique rugæ and small tubercles. Tegmina and wings surpassing the abdomen, the axillary vein of the former free; hind femora as long as the abdomen.

Mestobregma cincta Thomas.

A few specimens of this interesting insect have been taken in various portions of the state, but mainly in the more wooded regions. This insect appears to be by no means common. The description given by Thomas follows: Female: The head, seen from the side, shows the crown somewhat elevated, the eyes also standing high. Vertex deflexed,

broad, sub-hexagonal; the front portion prolonged; the margins continuous with the sides of the frontal costa. Frontal costa narrow above, gradually expanding below, and sulcate throughout. Pronotum short, the length not exceeding the depth, strongly contracted a little in advance of the middle; the disk somewhat rugose, that of the posterior lobe nearly flat; the median carina slightly elevated on the front lobes, twice distinctly notched; the middle portion shortest and rounded; the whole of the disk, especially the posterior lobe, more or less covered with small tubercles; lateral carinæ obsolete on the anterior lobes, and obtuse and indistinct on the posterior lobe; the posterior angle a little larger than a right-angle. Elytra and wings extend beyond the apex of the abdomen. Posterior femora rather short, not reaching the tip of the abdomen in the female; broad at base, with a sharp, elevated upper carina, which suddenly decreases about one-third of the length from the apex; the lower edge generally hairy. Antennæ longer than the head and pronotum, filiform.

Color.—Fuscous and pale yellowish-brown, or ash, about equally distributed in stripes and spots, the ash or yellowish-brown portion more or less mottled with fuscous dots and points. The dark on the head as follows: two stripes, running back from the eyes one from the upper, the other from the lower corner; the lower portion of the cheeks and the lower margin of the face; and some dots on the margin of the frontal costa. On the pronotum a broad pale stripe runs along each lateral carina, converging in front of the middle; the margins of the posterior portions are pale, jointed interiorly by a black stripe; the central space pale; the sides marked with alter-

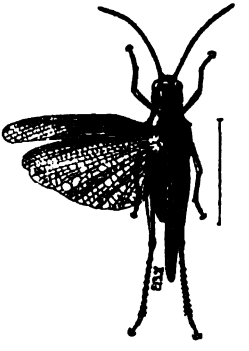


Fig. 99.—*Mestobregma cincta*, male. Original.

nate stripes of pale and fuscous. Elytra fuscous at the base, becoming transparent a little beyond the middle, where the netted nervules suddenly cease; a narrow whitish line along the angle; the lower field has two sub-quadrate black spots separated by an elongate whitish spot. Wings transparent; base greenish-yellow; a narrow fuscous band across the middle; apex pellucid, with a few fuscous dots at the tip. Posterior femora ash-colored, with three black spots on the upper margin of the outer face; base and a band on the inside black. Posterior tibiæ with a broad white ring near the base, rest blue. Tarsi yellow. Venter and pectus white.

Dimensions.—Length, 25 mm.; tegmina, 23 mm.; posterior femora, 14 mm.; posterior tibiæ, 12 mm.

This insect, shown in Fig. 99, is quite different from any other orthopterous insect found in Minnesota.

GENUS *Psinidia* Stål. (1873).

Head large; antennæ flattened; pronotum granulated, acute angled behind, very much compressed before the middle; median carina distinct with two notches; lateral carina distinct on posterior lobe, broken on the anterior lobes; wing-covers narrow, hind wings broad, both extending beyond the body.

LONG-HORNED LOCUST.

Psinidia fenestralis Serville.

This beautiful insect is not common in Minnesota, and only a single specimen was found late in August in a dying condition upon the hot sands of a sand bar in the Mississippi River opposite Gray Cloud Island. The insect is small, and when resting on the ground it is so much colored like it that it is not readily seen; when flying, however, it is a very conspicuous object with its large and crimson-colored wings.

Ash-colored, variegated with gray and dark brown; body beneath yellowish; hind femora grayish outside, black at base inside, a band beyond the middle and black at the apex, these bands are repeated outside; hind tibiæ whitish, with a black ring at each end, and one of the same color before the middle; wing-covers ashen gray, variegated with brown and black, transparent at the apex; hind wings pinkish-red salmon color or pale orange-yellow at the base, with a rather arcuate smoky black band; apex transparent in the female, more or less tipped with black in the male, the dark color usually connecting with the black band and enclosing a transparent patch.

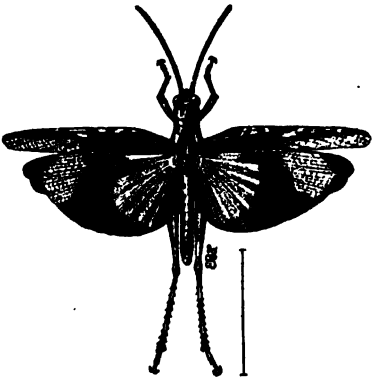


Fig. 100.—*Psinidia fenestralis*, male. Original.

Measurements.—Male: Length of body, 15 mm.; wing-covers, 19 mm.; posterior femora, 10 mm. Female: Length of body, about 25 mm.; wing-covers, 23 mm.; posterior femora, 13 mm.

This insect, (Fig. 100), is readily distinguished from the species of *Spharagemon* by the strongly constricted pronotum, the form of the antennæ, and the venation of the tegmina, which are narrow and have many of the cellules in hinder part of distal half two to four times as long as wide. The antennæ are unlike those of any other species of this sub-family, having depressed or prismatic joints, appearing almost ensiform next the base. Another peculiarity noticable is that on the distal third of the tegmina the maculation is restricted to the costal half. The species varies greatly in general coloration, according to environment, from pale dust-color to bright reddish-brown or even black. The most interesting feature is the variation in the

color of the wings, which may vary in specimens from the same spot, from dull white through yellow and orange to vermilion.

GENUS *Trimerotropis* Stål. (1873).

Vertex continuous with the median sulcus of the face; body covered with very short hairs; pronotum compressed before the middle, narrower in front than behind; slightly angled in front and acutely angled behind; median carina slight and broken by two wide notches before the middle; lateral carina distinct on the posterior lobe and broken on the anterior lobes; wing-covers long and narrow; hind wings narrowing to a point at the apex.

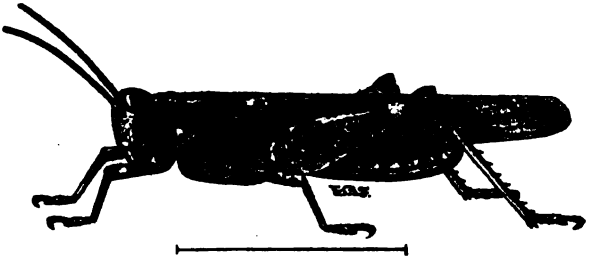


Fig. 101.—*Trimerotropis maritima*, male. Original.

Trimerotropis maritima Harr.

The Maritime Locust.

Head, pronotum, legs and posterior femora white, sprinkled with minute points and dots of black and brown; eyes ochraceous; inside of hind femora with two black spots; hind tibiæ light yellow, spines tipped with black; wing-covers also whitish, sprinkled more or less with black and brown points and spots, apex transparent; hind wings at base semi-transparent, pale yellow followed by an arcuate, narrow black band, more or less broken by the veins, outer third of wing transparent.

Measurements.—Male: Length of body, 23 mm.; wing-covers, 24 mm.; posterior femora, 13 mm. Female: Length of

body, 32 mm.; wing-covers, 33 mm.; posterior femora, 16 mm.

This is an easily recognized species. The sides of the pronotum vary considerably, being sometimes almost rounded, sometimes with a distinct tooth-like projection. The color of the insect varies with the soil of the locality,

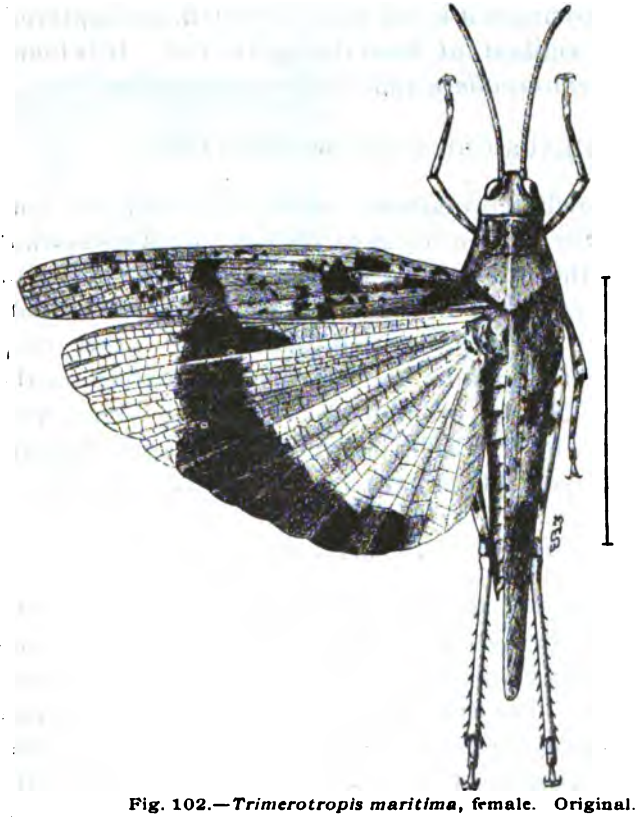


Fig. 102.—*Trimerotropis maritima*, female. Original.

the ground-color ranging from white to light brown, more or less sprinkled with dusky blotches, which are sometimes nearly obsolete, or again nearly confluent on the head, pronotum and base of tegmina. In places where the white sand of the river shores is mixed with small bits of bark the insects show numerous brownish spots agreeing with the color of the sand. Both sexes are illustrated in Figs. 101 and 102.

This beautiful insect is rather common in certain localities, like sandy shores of rivers and lakes. Its whole appearance shows it to be an inhabitant of white, or whitish sand. Here it delights to bask throughout the warmer portions of summer, and is especially numerous early in July. Though very common it is not easily detected, nor captured, as it is very vigilant, at least during the day. It is found with *Spharagemon collare* and *Dissosteira carolina*.

GENUS *Circotettix* Scudder (1876).

Eyes somewhat prominent; vertex channeled and continuous with the median sulcus of the face; head somewhat broader than the anterior lobes of the pronotum; posterior lobe of the pronotum broader and acute angled behind; median carina slightly elevated, with two rather deep notches before the middle; lateral carina indistinct on the posterior lobe, but not prominent. Wings and wing-covers longer than the body; the latter are of equal length throughout, with the apex oblique; the former are rather broad.

Circotettix verruculatus Kirby.

Ash gray, heavily mottled with black and gray; sometimes the black almost obscuring the entire head, thorax and wing-covers, thus giving the insect a very black appearance; abdomen black; hind femora with four more or less distinct black bands; hind tibiæ yellowish with a black band at the base, a broader one at the extremity and one before the middle; hind wings semi-transparent, light yellow at the base followed by a narrow, black, arcuate band; apex transparent, tipped with black; sometimes the transparent space is black, but of a lighter shade than the band.

Measurements:—Male: Length of body, 22 mm.; wing-covers, 24 mm.; posterior femora, 11 mm. Female: Length of body, 30 mm.; wing-covers, 28 mm.; posterior femora, 13 mm.

A number of specimens were captured among the rocks at the State Park near Taylor's Falls. It may be common if looked for at the proper time. It is readily confused with dark forms of *Spharagemon bolli*, but may be distinguished by the narrow wing band, enlarged radial veins, pale hind tibiæ, and distinctly two-notched pronotal carina. In color it varies from a dark gray or brown to black sprinkled with ashy, darkest on the head and pronotum, palest on base of hind thighs, and with the tegmina distinctly trifasciate. Its "song" in flight is the loudest produced by any of our locusts, and consists of a series of separate notes, clicks or snaps, not a rattle, and is readily distinguished by this peculiar snapping quality. It is very shy and difficult to approach during the warmer part of the day, when it often flies away for a distance of several rods and circles about, returning to the place whence it started, like our common C-butterfly, or dances up and down in the air, snapping loudly. The female sometimes makes a soft flutter or shuffle of wings in flight, probably corresponding to the snapping of the male, and both sexes can fly silently at will. The male stridulates when at rest, by rubbing the hind thighs against the tegmina, producing a "scritching" sound, audible at a distance of three or four feet. The intercalary vein is toothed, in a low but continuous series, for its entire length in the male, and on the distal half or more in the female, in which the teeth are lower and barely perceptible. A male insect is illustrated in Fig. 103.

Fig 103.—*Circotettix verruculatus*. male. Original.

SUB-FAMILY ACRIDIINÆ.

This sub-family of locusts, distinguished by an armed prosternum, is well represented in our state, and some of the most injurious insects known to our farmers belong here. Only two groups of Acridiinæ occur here, the *Acridia* and *Melanopli*. To the former belong the very large locusts with the mesosternal lobes longer than broad, the inner margin straight, and to the latter smaller insects, with the mesosternal lobes transverse or equally long and broad, the inner margin usually rounded. The *Acridia* contain but one genus, the *Schistocerca;* several species of this genus occur in Minnesota.

GENUS *Schistocerca* Stål.

Large size, vertex concave; median carina of pronotum distinct; lateral carina rounded; prosternum provided with a long, stout, blunt spine; wings well developed, as long or longer than the body. Last segment of male not swollen.

A number of species have been reported from Minnesota, and the following ones were captured in 1896. *Sch. emarginata* Uhler, *Sch. rubiginosa* Harr., and *Sch. alutacea* Harr. *Sch. americana* Drury is a southern insect, yet they can extend as far north as Minnesota, as indicated by the capture of one of these insects in the southeastern corner of the state.

Schistocerca alutacea Harris.

This large insect occurred early in July in large numbers at Gray Cloud Island, in a stubble field, which was overgrown with large plants of Rudbeckia and other weeds. The insect, when fresh, is dirty olive-brown or green, with a rather broad, more or less bright yellow longitudinal stripe on the top of the head and pronotum; wing-covers brown, sometimes marked with darker spots and dots; along the inner margin is a bright yellow stripe which becomes lost near the apex; hind wings transparent, yellowish at the base and becoming brownish towards the apex.

Measurements.—Male: Length of body, 28-32 mm.; wing-covers, 25-27 mm.; hind femora, 16-20 mm. Female: Length of body, 48 mm.; wing-covers, 39 mm.; hind femora, 24 mm.

Schistocerca emarginata Uhler.

This species occurs with *alutacea*, but is decidedly more common. Both species are so closely allied, that forms occur that seem to belong as much to the one species than to the other. It is shown in Fig. 104.

Fig. 104.—*Schistocerca emarginata*, female. Original.

Color, a pale reddish-brown, tinged with green. A distinct median yellow stripe reaches from the vertex to the tip of the pronotum, and extends upon the suture of the *elytra*. A row of distinct black punctures on each margin of the frontal costa, and a row across the upper part of the clypeus. Palpi and antennæ yellow, and the sides of the the pronotum sparsely sprinkled with yellow dots. Elytra translucent, pale reddish-brown; nerves darkest. Wings transparent, tinged with greenish-yellow at the base; nerves and nervules dull yellow, darkest near the middle of the outer border, slightly tinged with red near the anterior border. Anterior and middle legs greenish externally; striped with black internally. Posterior femora pale green; upper margin of the disk marked with a row of black dots. Posterior tibiæ with the inner face black; outer face greenish-purple. Posterior margin of each abdominal segment marked with a ring of black dots. Same size as *alutacea*.

Schistocerca rubiginosa Harris.

Only two specimens of this species have been seen, both captured in the southeastern part of the state among the wooded bluffs of the Mississippi River. It is light rust-red, rather uniform. Elytra opaque, rather paler on the overlapping portion, without spots, or very brightly sprinkled with small, darker colored spots. Wings transparent, yellowish at base, slightly reddish toward the tip; veins blackish. Posterior femora reddish; the flat disk whitish, with a row of black dots above and below; apex with a lunate black spot on the side. Spines of the tibiæ whitish, tipped with black.

It is slightly smaller than *alutacea*, and differs from it by its redder color, and the absence of the yellow stripe on head, pronotum and wing-covers.

Schistocerca americana Drury.

This fine and large locust is common in the south, where it sometimes assumes a migratory habit and becomes very injurious to crops. Its large wings enable it to fly long distances. This species is well known, being illustrated in almost every book on entomology. It is reddish-brown, with a slight vermilion tint. A yellow stripe extends from the

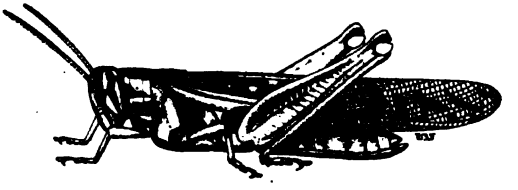


Fig. 105.—*Schistocerca americana*, male. Original.

vertex along the middle of the head and pronotum, and also upon the suture of the closed elytra as far as the tip of the abdomen. A dark brown line down the cheeks below the eyes. On the sides of the pronotum is a yellow stripe extending from the sub-marginal to the last cross-incision, directed a little obliquely downward; below this is a brown stripe;

then a narrow yellow stripe directed obliquely upward; lower margin yellow. The wing-covers opaque and reddish at base, rest semi-transparent; a narrow white stripe on the lower margin, next the base; the disk and apical half marked with large, cellular, fuscous spots. Wings transparent, nerves at the base and inner portion yellowish-

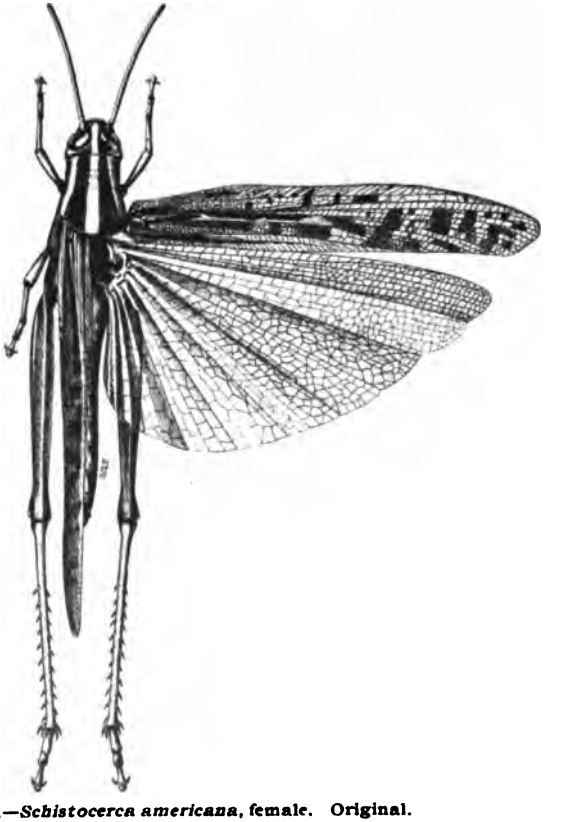


Fig. 106.—*Schistocerca americana*, female. Original.

white, of the other portions black. Legs bright vermilion. Posterior femora have a row of black dots along the upper and lower margins of the disk and one through the middle; spines of posterior tibiæ yellow, tipped with black. Each section of the abdomen has a ring of dusky dots on its posterior margin.

Measurements.—Male: Length of body, about 43 mm.; wing-covers, 45 mm.; posterior femora, 24 mm. Female: Length of body, 52 mm.; wing covers, 54 mm.; posterior femora, 28 mm.

Both sexes are illustrated in Figs. 105 and 106.

The group *Melanopli* contains only three genera found in Minnesota, viz. *Hesperotettix* Scudder, *Melanoplus* Stål, and *Phœtaliotes* Scudder.

A. Subgenital plate of male furnished with a distinct sub-apical tubercle (i. e. one in which the apical margin does not pass through and form a part of the summit of the tubercle, but where it is distinctly separated from the summit), but not otherwise tumescent.

Hesperotettix.

AA. Subgenital plate of male with no distinct sub-apical tubercle, but often apically prolonged or tumescent.

B. Head not large in proportion to pronotum, nor prominent, but little longer than the prozona; pronotum in no way sub-sellate, nor flaring in front; tegmina, when fully developed, narrow; venation sharp and clearly defined.....*Melanoplus.*

BB. Head large in proportion to pronotum, nearly half as long again as the long prozona; pronotum faintly sub-sellate, feebly flaring in front to receive the head; tegmina, when fully developed, broad; venation loose and ill defined.

Phœtaliotes.

GENUS *Hesperotettix* Scudder (1875).

Head not very prominent; vertex very narrow between the eyes, with a slight median pit; the fastigium broadening considerably in front, declivant, shallowly sulcate in the middle, the sides rounded; front straight, a little (female) or considerably (male) oblique; the frontal costa equal, scarcely contracted at the extreme summit; antennæ slightly longer than the head and prothorax together; eyes

slightly prominent, a little more so in the male than the female. Pronotum rather long, nearly equal, broadening a very little posteriorly, transversely arched, with a scarcely perceptible median tectiform carina and well rounded lateral margins; the hind scarcely longer than the frontal lobe; the hind border delicately marginate, obtuse angled; prosternal thorn rather long, conical, compressed, bluntly pointed, meso- and metastethia together much longer than broad. Tegmina and wings reaching the tip of the abdomen. Femora as long as the abdomen, the superior carina slight, unarmed; hind tibiæ slender, the spines of either side of equal length, scarcely diverging, the upper lateral margins smooth and rounded; first joint of hind tarsi scarcely longer than the third, the second small, with a large inferior apical lobe; pulvillus large, nearly twice as long as broad.

Hesperotettix pratensis Scudder.

(PALE-GREEN LOCUST.)

Head yellowish-green, sparsely punctate with fuscous in front, the lower portion of the face more or less obscured with purplish, a short fuscous stripe depending from the eye, in front of which the callosity is livid; vertex with a more or less distinct, rather narrow, fuscous or blackish stripe, narrowing anteriorly, and ordinarily with a median thread of yellow, the fastigium generally discolored, sometimes and especially in the female reddish. Pronotum scarcely (male) or slightly (female) increasing in breadth from the front backward, equally throughout and with no angle in the middle, yellowish-green. Tegmina of about the length of the abdomen in both sexes, green or yellowish green. Legs green, the fore

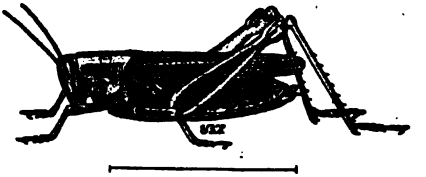


Fig. 107.—*Hesperotettix pratensis*, female. Original.

and middle femora more or less plainly annulate with coral red; hind tibiæ pale bluish-green, becoming more or less yellowish apically, the spines pallid on their basal, blackish-brown on their apical half; hind tarsi pale green, more or less yellowish.

Length of body, male, 18.5 mm., female, 30 mm.; antennæ, male, 8.25 mm., female, 10.25 mm.; tegmina, male, 13 mm., female, 20 mm.; hind femora, male, 11.6 mm., female, 17.5 mm.

A female of this beautiful green locust is shown in Fig. 107.

GENUS *Melanoplus** Stål.

Head rounded on top, not large in proportion to pronotum, nor prominent, but little longer than prozona, unless the latter is distinctly transverse; vertex continuous with the median sulcus of the face, with the portion between the eyes channelled; face with the lateral carina sharply defined; eyes prominent, nearly straight in front and rounded behind, antennæ slender, extending to the tip of the pronotum in the female, and beyond in the male: pronotum with a distinct median carina, the lateral carina obtuse and the transverse incision more or less distinct. Tegmina, when fully developed, narrow, rarely rather broad, but then very distinctly tapering, more or less tapering in the distal half; as long, longer or shorter than the abdomen; hind wings somewhat shorter than the tegmina. First joint of hind tarsi as long as the last joint; pulvilli between the claws large; last joint of abdomen of the male much swollen, cerci of male very variable, very rarely styliform, and then the subgenital plate is either exceptionally broad or only moderately narrow, and the apical margin elevated.

This American genus of locusts is very well represented in Minnesota, and many more species will be found upon closer exploration. Besides those described the following species have been found in our state: *viridipes* Walsh;

*Black armor.

fasciatus Scudder; *extremus* Walker; *comptus* Scudder; *Packardii* Scudder; *infantilis* Scudder; *viola* Thomas; and *femoratus*, Burmeister, but no specimens have been seen by the writer.

A. Tegmina conspicuously shorter than the abdomen, often no longer than pronotum; furcula* almost always developed feebly, generally no longer than the last dorsal segment from which it arises.

b. Cerci of male beyond the middle either equal or tapering, sometimes simply styliform throughout, the tip usually more or less pointed, but sometimes broad or truncate; metasternal lobes of male attingent or sub-attingent.

c. Prozona, at least in male, much longer than broad, the disk of the whole pronotum more than twice as long as the middle breadth, the median carina percurrent, equal; interval between mesosternal lobes of male twice as long as broad.....*Scudderi.*

cc. Prozona, even in male, transverse, sub-quadrate or slightly longitudinal, the disk of the whole pronotum less than twice as long as middle breadth, the median carina often sub-obsolete between the sulci; interspace between the mesosternal lobes of the male not more than half as long again as broad.....*Dawsoni.*

bb. Cerci of male more or less expanded apically, so as to be broader at some point below the middle than at the middle, spatulate or sub-spatulate; metasternal lobes of male separated by a variable interval.

c. Sub-genital plate of male short and broad, its apical breadth equal to or surpassing the length of its lateral margin.....*Blatchleyi.*

*Prof. Scudder calls the processes of last dorsal segment of the male abdomen *the furcula*.

cc. Sub-genital plate of male distinctly narrower than long, often narrowing apically...*gracilis*.

AA. Tegmina nearly or quite as long as or longer than the abdomen; furcula usually well developed, generally at least a quarter as long as the supra-anal plate, but sometimes obsolete.

b. Cerci of male rapidly expanding from the base towards the middle, as a whole broad and short, flabellate, rarely twice as long as broad, not expanded apically.....*occidentalis*.

bb. Cerci of male tapering from the very base towards the middle, rarely equal in basal portion, generally long and slender, and rarely as little as twice as long as broad.

c. Cerci of male beyond the middle either equal or tapering, the tip usually slender or acuminate, never bifurcate. Apical margin of sub-genital plate of male notched.

d. Tegmina extending beyond hind femora, if at all, by not more than the length of the pronotum, generally by much less than that; prozona of male quadrate or very feebly transverse; cerci of male generally almost or quite twice as long as broad. .....*atlanis*.

dd. Tegmina extending beyond hind femora by the length of the pronotum or nearly as much, often by the length of head and pronotum combined; prozona of male generally strongly transverse; cerci of male not more than half as long again as broad..... .....*spretus*.

e. Sub-genital plate of male as broad or nearly as broad at apex as at base, generally elevated apically and often notched (generally narrowly); cerci usually narrowing but little on basal

half, the apical half equal and symmetrical, bluntly rounded (rarely truncate or angulate) apically.

f. Interspace between mesosternal lobes of male distinctly longer, generally much longer than broad, and much narrower than the lobes; metasternal lobes attingent or sub-attingent in the male.

g. Sub-genital plate of male broad, at least as broad as long; cerci incurved feebly and gently, or not at all.....*Dawsoni.*

gg. Sub-genital plate of male rather narrow, narrower than long, although short; cerci abruptly incurved apically.....*Gladstoni.*

ff. Interspace between mesosternal lobes of male quadrate, almost or a little transverse and but little narrower than the lobes; metasternal lobes of male only approximate.....*borealis.*

ee. Sub-genital plate of male conspicuously narrower at apex than at base (generally only half as wide), rarely at all elevated at apex above the lateral margins and never notched; cerci always distinctly narrowing on basal half, the upper angle of the apex prolonged and often sub-acuminate.....*femur-rubrum.*

cc. Cerci of male more or less expanded apically, so as to be broader at some point beyond the middle than at the middle, spatulate or subspatulate or apically bifurcate.

d. Cerci of male simply spatulate or sub-spatulate, at most moderately broad, apically entire and no broader than at base; furcula always developed as distinct denticulations.

e. Furcula of male not more than a third as long as the supra-anal plate; tegmina lightly maculate or immaculate. *angustipennis.*

ee. Furcula of male more than a third as long as the supra-anal plate; tegmina usually heavily maculate..... *impiger.*

dd. Cerci of male apically bifurcate, or with an inferior sub-median process or abrupt angulation, or else expanded so as to be distinctly, generally much, broader apically than at the extreme base; furcula wanting or minute.

e. Size smaller or medium; cerci of male always bifurcate or with an inferior sub-median process or angulation; supra-anal plate pretty regularly triangular with straight or feebly convex lateral margins: furcula usually distinctly developed; prosternal spine usually short.

f. Furcula of male consisting of slender spines, longer than the last dorsal segment; base of lateral margins of sub-genital plate incurved..... *minor.*

ff. Furcula of male consisting of brief triangular lobes; base of lateral margins of sub-genital plate not incurved..... *luridus.*

ee. Size medium or large; cerci of male rarely bifurcate or with an inferior process (and then the insect is of a large size, which it never is in the alternate category, and the supra-anal plate is distinctly shield-shaped, the apical half tapering with much greater rapidity than the basal; or the furcula is absent; or the interspace between the mesosternal lobes of the male is three times as long as broad, which it never is in the alternate category); supra-anal plate of variable shape; furcula either absent or very minutely developed; prosternal spine usually long.

f. Interspace between mesosternal lobes of male nearly, fully, or much more than twice as long as broad; of female generally as long as broad, rarely quadrate; prosternal spine generally long; tegmina usually clear, or with a marked distinction in color between the dorsal and lateral areas, or with the angle between the two marked by a conspicuous light colored stripe; head less prominent and with less prominent eyes than in the alternate category, the front margin of the pronotum in no way flaring to receive the head.

g. Furcula of male entirely absent, or present only as a minute point or bead; hind tibiæ generally yellow, but sometimes red.

differentialis.

gg. Furcula of male distinctly present, though always very small, angulate, the angle rarely produced; hind tibiæ never yellow, usually red, rarely purplish or yellow at tip.....*bivittatus.*

ff. Interspace between mesosternal lobe of male sub-quadrate; of female transverse; prosternal spines short; tegmina maculate with roundish fuscous spots; eyes of male and head prominent, the front margin of the pronotum flaring to receive the head.....*punctulatus.*

Melanoplus Scudderi Uhler.

Short winged, of medium or rather small size, ferrugineo-fuscous, a little lighter beneath. Head not prominent, dark testaceous, much mottled with fuscous, above almost wholly infuscated, with an obscure fuscous post-ocular band; vertex somewhat tumid, scarcely elevated above the pronotum; antennæ ferruginous, about four-fifths (male) or less than two-thirds (female) as long as the hind femora. Pronotum often heavily ferruginous on the disk, the lateral lobes with a post-ocular piceous belt; disk broadly convex, passing by a distinct but everywhere distinctly rounded shoulder into the at first very steeply declivent and afterwards vertical lateral lobes; median carina distinct, delicate and equal throughout. Prosternal spine not very long, appressed cylindrical, tapering apically, bluntly pointed, erect. Tegmina about as long as the pronotum, broad ovate, overlapping; wings not half the length of the tegmina. Fore and middle femora slightly tumid in the male; hind femora ferrugineo-testaceous, occasionally with an olivea-

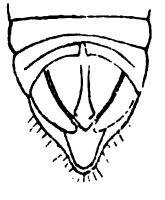


Fig. 108.—*Melanoplus Scudderi*, tip of male abdomen. Original.

ceus tinge, feebly bimaculate with fuscous above, the spots often extending half way across the inner face, the lower face castaneous, occasionally ruddy, the geniculars are black; hind tibiæ bright red sometimes feeby infuscated towards the base, and with a fuscous patellar spot, the spines black in the apical half, crowded, eleven to sixteen, usually twelve to thirteen, in number in the outer series. Extremity of male abdomen as shown in Fig. 108.

Length of body, male, 17 mm., female, 22 mm.; antennæ, male and female 8 mm.; tegmina, male, 5 mm., female, 5.25 mm.; hind femora, male, 10 mm., female, 12.75 mm.

This is not a common locust, but is sometimes found late in summer, in dry places.

Melanoplus Dawsoni Scudder.

Short or long wing, of medium or rather small size, obscure fusco-testaceous. Head slightly prominent in the male only, olivaceo-testaceous, infuscated above with a broad piceous, post-ocular band; vertex tumid, distinctly elevated above the pronotum, the interspace between the eyes rather broad, at least twice as broad as the first antennal joint; eyes not very large and prominent; antennæ ferruginous, four-fifths (male), or three-fifths (female), as long as the hind femora. Pronotum sub-equal (male) or distinctly compressed above anteriorly (female), short, the disk transversely a little convex and passing into the vertical lateral lobes by a rounded angle, which is nevertheless so abrupt as to form, at least in the male, tolerably distinct lateral carinæ; lateral lobes lighter colored below than the disk, above on the prozona a broad, lustrous, dark colored band, sometimes obsolete,

Fig. 110.—*Melanoplus Dawsoni*, female. Original.

sometimes deepening to piceous; median carina slight; prosternal spine very short and blunt. Tegmina brownish-fuscous, more or less feebly flecked with fuscous, and either greatly surpassing the hind femora, moderately broad and sub-equal nearly to the well rounded tip, or ovate-lanceolate apically sub-acuminate, a little longer than the pronotum only; wings, when fully developed ample, hyaline, with pale brownish-fuscous veins. Fore femora of male greatly enlarged, hind femora luteo- or ferrugineo-testaceous, very obliquely and broadly bifasciate with blackish fuscous above and outside, with a basal patch of the same, the

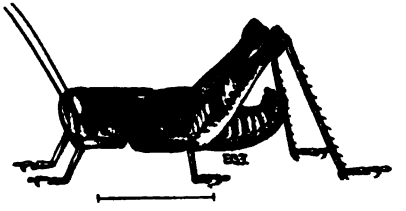


Fig. 109.—*Melanoplus Dawsoni*, male. Original.

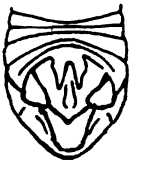


Fig. 111.—*Melanoplus Dawsoni*, tip of male abdomen. Original.

whole sometimes reduced to mere clouds, the genicular arc and sometimes the whole geniculation blackish fuscous; hind tibiæ wholly red, the spines black except at base, ten to thirteen in number in the outer series.

Extremity of male abdomen as shown in Fig. 111.

Length of body, male, 16 mm., female, 18.5 mm.; antennæ, male, 7.5 mm., female 6.25 mm.; tegmina, male and female, 5.25 mm.; hind femora, male, 9 mm., female, 10.5 mm.

The short-winged form of this species is found rather abundantly upon the flowersof the various species of golden rod. Both sexes are illustrated in Figs. 109 and 110.

Melanoplus Blatchleyi Scudder.

Short winged, of moderately large size, cinereo-fuscous with an olivaceous tinge. Head somewhat prominent, oli-

vaceo-testaceous variably but generally considerably infuscated, above dark fuscous, separated by a testaceous stripe from the broad piceous post-ocular band; vertex gently tumid, feebly elevated above the pronotum, the interspace between the eyes half as broad again (male) or twice as broad (female) as the first antennal joint; eyes moderately large and prominent; antennæ rufo-testaceous, scarcely shorter than (male), or nearly two-thirds as long as (female) the hind femora. Pronotum sub-equal, the sides with

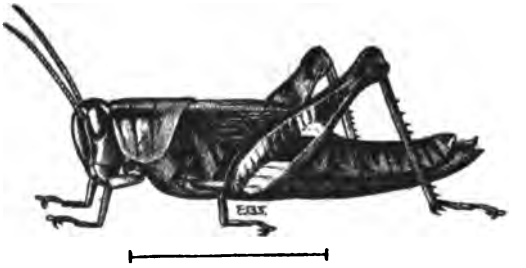


Fig. 113.—*Melanoplus Blatchleyi*, female. Original.

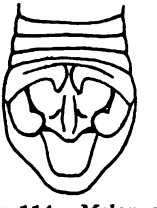


Fig. 114.—*Melanoplus Blatchleyi*, tip of male abdomen. Original.

a broad piceous post-ocular band confined to the prozona in the male, the same being wholly obsolete, obscure, or confined to the upper limits of the lateral lobes in the female; disk very broadly convex, passing by a distinct but blunt angulation forming feeble lateral carina into the inferiorly vertical lateral lobes; median carina distinct but not very sharp on the metazona. Prosternal spine long, appressed cylindrical, blunt retrorse. Tegmina abbreviate, a little longer than the pronotum, over lapping, very broad just beyond the base and rapidly narrowing, short sublanceolate, the costal margin roundly angulate, apically sub-acuminate, brownish-fuscous the dorsal field often cinereous, the lateral often feebly flecked with fuscous. Fore and middle femora very tumid in the male; hind femora testaceous or flavo-testaceous, heavily and broadly but sometimes confusedly bifasciate with blackish-fuscous, the geniculation blackish, the inferior face pale flavous, pallid apically; hind tibiæ red,

blackish at the base, followed by an obscure pallid annulus, below which the red is feebly infuscated, the spines black on their apical half, ten to eleven, rarely nine, in number on the outer series.

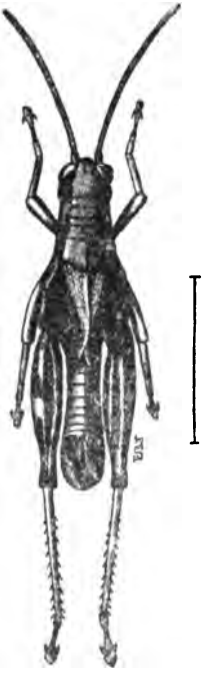


Fig. 112.—*Melanoplus Blatchleyi*, male. Original.

Extremity of male abdomen as shown in Fig. 94.

Length of body, male, 23 mm., female, 24 mm.; antennæ, male, 14 mm., female, 10 mm.; tegmina, male, 9.5 mm., female, 8.5 mm.; hind femora, male, 15 mm., female, 13.5 mm.

This insect, both sexes of which are illustrated in Figs. 112 and 113, is very common in Minnesota, and wherever it occurs it is found in large and destructive numbers. It prefers the edges of forests, or places overgrown with bushes and vines. The grapevine especially is preferred by these locusts, and they soon destroy its foliage by eating big holes in the leaves. It is an insect that can become very destructive. In 1896, during July, not a single entire leaf could be found upon Gray Cloud Island, as this locust was everywhere in large numbers.

Melanoplus gracilis Bruner.

Short winged, a little below the medium size, brownish-testaceous above, luteo-flavous, the whole tinged with green, with bright green hind legs. Head hardly prominent, luteo-flavous, generally tinted with green and somewhat embrowned, above brownish-testaceous with a greenish tinge, sometimes separated by a distinct slender flavous stripe from

the broad post-ocular band. Frontal costa prominent; eyes moderate in size. Pronotum subequal, faintly enlarging posteriorly, above brownish-testaceous, the lateral lobes with a very broad and conspicuous piceous percurrent post-ocular belt above, below varying from bright flavous to flavo-testaceous, the disk very broadly sub-tectate, passing by an abrupt but rounded shoulder, forming feeble percurrent lateral carinæ, into the vertical lateral lobes; median carina low but distinct. Prosternal spine large, conical, blunt, suberect. Tegmina abbreviate, about the length of the prozona, lateral, lanceolate, the costal margin convex, the inner nearly straight, fully three times as long as broad, brownish fuscous. Fore and middle femora considerably tumid in the male; hind femora very slender, green, the whole geniculation blackish-fuscous, the under surface flavous; hind tibiæ green, with a basal, feeble, fuscous annulus, the spines black in the apical half, eleven to twelve in number in the outer series. Abdomen ferrugineo-fuscous, flavescent, compressed, with a distinct median carina, the extremity of the male abdomen considerably clavate, much recurved.

Length of body, male, 14 mm., female, 19 mm.; antennæ, male, 8.5 mm., female, 7.75 mm.; tegmina, male, 3 mm., female, 4 mm.; hind femora, male, 10 mm., female, 11.25 mm.

This species is also found in low and open woods, but is not common, only four females having been caught in July, in society with *Blatchleyi*.

Melanoplus occidentalis Thomas.

Of medium or rather small size. Head very slightly elevated, a very little arched; fastigium rather shallow, the margins in front of the eyes blunt; frontal costa more than usually prominent; eyes rather prominent, anteriorly truncate. Pronotum enlarging on the metazona, laterally subtumid in an irregular way on the prozona, the metazona faintly punctate; front margin feebly convex, with a feeble median emargination; hind margin roundly obtus-angulate;

median carina distinct on the metazona, faint on the prozona, obsolete between the sulci; sides of the pronotum hardly shouldered, or with very rounded shoulders; transverse sulci of prozona pretty distinct and continuous. Prosternal spine rather short, appressed conical, broadly rounded on tip. Tegmina extending to or a little beyond the tip of the abdomen, slender, scarcely tapering, profusely maculate throughout. General color ferruginous brown above, mottled strongly with blackish-fuscous, livid brown below; a blackish-brown median stripe, broadening posteriorly, passes from between the eyes to the back of the head, but seldom continues, and then less deeply, upon the pronotum; the face and genæ vary from yellow to testaceous and are seldom blotched by dusky colors, excepting on the genæ. Tegmina dark brownish cinereous with a slender median yellow stripe, frequently broken by quadrate fuscous or blackish spots, and similar spots are scattered rather distantly all over the tegmina, giving them an unusually speckled appearance. Hind femora variable, either with oblique pale patches on a dark ground or—and generally—the reverse; hind tibiæ glaucous, with black-tipped spines, ten or eleven in number in the outer series.

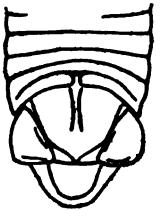


Fig. 115.—*Melanoplus occidentalis*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 115.

Length of body, male, 18 mm., female, 25 mm.; antennæ, male, 9.5 mm., female, 10.25 mm.; tegmina, male, 16 mm., female, 21 mm.; hind femora, male, 11.5 mm., female, 14 mm.

Only a few of this species were found in Otter Tail County.

Melanoplus atlanis Riley.

THE LESSER MIGRATORY LOCUST.

From medium to a little above medium size, dark grisco-fuscous, often tinged more or less heavily with ferruginous; head a little prominent, olivaceo-testaceous freckled with

fuscous, above more or less infuscated, sometimes diffusing the whole, sometimes confined to two divergent longitudinal stripes, with a broad, piceous, post-ocular band; vertex rather tumid, somewhat elevated above the pronotum, the interspace between the eyes nearly twice as broad as the first antennal joint in both sexes; fastigium steeply declivent, shallowly sulcate; frontal costa rather prominent, irregularly punctate; eyes moderate, rather prominent in the male. Pronotum rather short, feebly and angularly constricted in the middle, the broad angulation at the principal sulcus and produced mostly by the posterior expansion of the metazona, more or less infuscated and often also ferruginous above, the lateral lobes with a generally distinct and entire but sometimes broken or maculate, broad, piceous, post-ocular band, confined to the prozona; disk broadly convex and passing into the vertical lateral lobes somewhat abruptly but with a well-rounded shoulder, simulating but nowhere really forming distinct lateral carinæ; median carina distinct and well marked in the metazona, obscure and generally sub-obsolete on the prozona if not indeed obsolete, particularly between the sulci and in the female. Prosternal spine variable, usually short, conical, a little blunt, slightly appressed, erect (male) or short appressed subconical, very blunt, erect (female). Tegmina usually surpassing considerably the hind femora, occasionally and especially

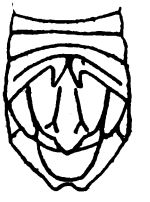


Fig. 116.—*Melanoplus atlanis*, tip of male abdomen. Original.

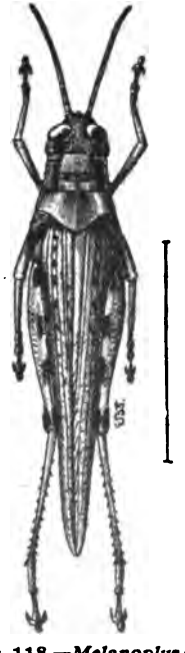


Fig. 118.—*Melanoplus atlanis*, female. Original.

in the female only a little, slender, feebly tapering, brownish-fuscous, nearly always flecked slightly with fuscous throughout the discoidal area; wings rather broad, hyaline, the veins mostly testaceous, the apex sometimes faintly infumate. Fore and middle femora of male somewhat tumid; hind femora luteo- or flavo-testaceous, obscurely broadly and obliquely bifasciate with fuscous besides the fuscous base, the inner surface mostly flavous, more or less clouded with fuscous, the lower surface externally flushed with roseate, the geniculation mostly fucous; hind tibiæ normally

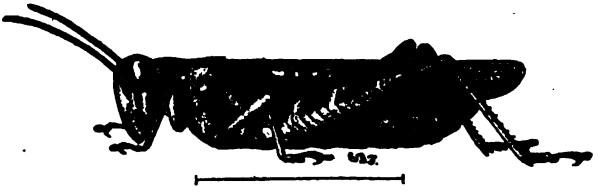


Fig. 117.—*Melanoplus atlanis*, male. Original.

rather bright red, often feebly pallescent at base, with a faint fuscous patellar spot, but not infrequently pale red or pale green or pale yellow, or even dark blue, the spines black beyond the base, nine to twelve in number in the outer series.

Extremity of male abdomen as shown in Fig. 116; male and female shown in Figs. 117 and 118.

Length of body, male, 21.5 mm., female, 24 mm.; antennæ, male, 10 mm., female, 7.5 mm.; tegmina, male and female, 20 mm.; hind femora, male, 12.5 mm., female 12.75 mm.

This is one of our most injurious locusts, and almost always found in our state in destructive numbers. It and *Camnula pellucida*, have caused serious losses in many parts of the state; it prefers higher and dryer regions, or a wooded or mixed country, to the open prairies, where, however, it also occurs not infrequently in very large armies, while the latter species is fond of low and moist localities. As a general rule both species do not remain for a number of years in destructive numbers in the same locality; this is no doubt

owing to the large numbers of parasites which soon become so numerous as to almost annihilate their host. This insect is single brooded in Minnesota. Its life-history, with illustration, is given elsewhere.

Melanoplus spretus Uhler.

THE ROCKY-MOUNTAIN MIGRATORY LOCUST.

Of large size, but of slender form, light griseo-fuscous, more or less cinereous, and often tinged to a greater or less degree with ferruginous. Head somewhat prominent, light fusco-olivaceous, with a broad, piceous, post-ocular band, and above more or less infuscated or dulled in color, often with a pair of longitudinal fuscous stripes; vertex rather tumid, raised considerably above the level of the pronotum; fastigium steeply declivent, rather deeply (male) or shallowly (female) sulcate throughout; frontal costa moderately prominent, distinctly failing to reach the clypeus; eyes not very large nor very prominent. Pronotum very short, equal on the prozona, expanding somewhat on the metazona, light brownish fuscous, often ferruginous, the lateral lobes with a much broken and maculate post-ocular piceous or dark fuscous band confluent to the prozona, the disk broadly convex, passing into the vertical lateral lobes by a rounded angle forming a blunt shoulder on the metazona and posterior section of the prozona only; median carina distinct on the metazona, feeble and often sub-obsolete on the prozona. Prosternal spine rather long, appressed, feebly conical, very blunt, erect, shorter in the female than in the male. Tegmina exceptionally long, far surpassing the hind femora, not very narrow, sub-equal, brownish testaceous, heavily flecked with blackish fuscous, usually through the discoidal area but sometimes confined to the middle line; wings ample, hyaline, the

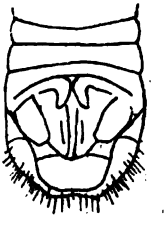


Fig. 119.—*Melanoplus spretus*, tip of male abdomen. 3 Original.

veins mostly fuscous. Fore and middle femora only a little tumid in the male; hind femora testaceo-ferruginous clouded with fuscous above, particularly in broad basal, pre-median and post-median patches, the geniculation mostly blackish-fuscous, the lower genicular lobe pallid-testaceous with a basal blackish bar, the inferior surface, especially externally, flushed with roseate; hind tibiæ bright red without, the spines black almost to the very base, ten to eleven, rarely twelve, in number in the outer series.

Extremity of male abdomen as shown in Fig. 119.

Length of body, male, 25 mm., female, 28 mm.; antennæ, male, 9 mm., female, 8.75 mm.; tegmina, male, 25.5 mm., female, 27.5 mm.; hind femora, male and female, 14 mm.

This is the well known "Rocky-Mountain Locust" or "Destructive Locust." The insect is not native in our state, but belongs to dry foot-hills on the eastern slope of the Rocky Mountains. Many sad experiences have shown that this insect can readily reach our state, however; and cause untold losses, even driving the farmers away from their homes. The life-history of this insect has been given elsewhere, hence it is not necessary to repeat it here.

Melanoplus Gladstoni Bruner.

Very dark testaceous, much infuscated, especially above. Head not prominent, luteo-castaneous, more or less clouded or blotched with fuscous, above wholly fuscous, with a narrow, posteriorly broadening, testaceous stripe, following the posterior edge of the eye and separating the vertex from a piceous or blackish-fuscous post-ocular band; vertex gently tumid, very slightly elevated above the pronotum; fastigium steeply declivent, broadly sulcate throughout; frontal costa rather prominent; eyes moderately large, not very prominent. Pronotum subequal, feebly enlarging on the metazona, ferrugineo-testaceous, much infuscated on the disk, the lateral lobes with a broad, more or less distinct, dark, sometimes piceous band crossing the prozona above; disk nearly

plane, passing by a tolerably distinct but rounded angle into the anteriorly slightly tumid vertical lateral lobes; median carina slight, percurrent, somewhat feebler and blunter on the prozona than on the metazona. Prosternal spine rather stout, moderately long, appressed conical, blunt, feebly retrorse. Tegmina reaching and sometimes a little surpassing the tips of the hind femora, moderately slender, distinctly tapering, brownish-fuscous, distinctly but not conspicuously maculate in the discoidal area; wings hyaline, with mostly brownish-fuscous veins. Fore femora of male not greatly tumid; hind femora flavo-testaceous, twice broadly and very obliquely banded with blackish fuscous, with a basal patch of the same, all sometimes confluent on the outer face, which it then nearly fills, the lower face and lower half of the inner face immaculate, the genicular arc black; hind tibiæ faintly valgate, red with an inconspicuous fuscous patellar spot, the spines black except their pallid bases, ten to twelve, usually eleven, in number in outer series.

Fig. 120.—*Melanoplus Gladstoni*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 120.

Length of body, male, 20 mm., female, 23 mm.; antennæ, male and female, 9 mm.; tegmina, male and female, 16 mm.; hind femora, male, 12 mm., female, 13.25 mm.

A number of these locusts were captured in October in the western part of the state (Brown's Valley); they vary from typical specimens by possessing red tibiæ.

Melanoplus femur-rubrum DeGeer.

COMMON RED-LEGGED LOCUST.

Of medium size, brownish-fuscous, often with a more or less feeble ferruginous tinge, particularly in the female. Head a little prominent, olivaceo-plumbeous, above much infuscated, especially in a pair of widening stripes behind the lateral margins of the fastigium, and with a piceous post-ocular

stripe; fastigium strongly declivent, more or less sulcate; frontal costa just failing to reach the clypeus, subequal, as broad as the interspace between the eyes, sulcate at and below the ocellus, bi-seriately punctate above; eyes moderately prominent in the male, not at all so in the female. Pronotum feebly and rather regularly expanding posteriorly, the disk faintly convex and passing by a well-rounded shoulder

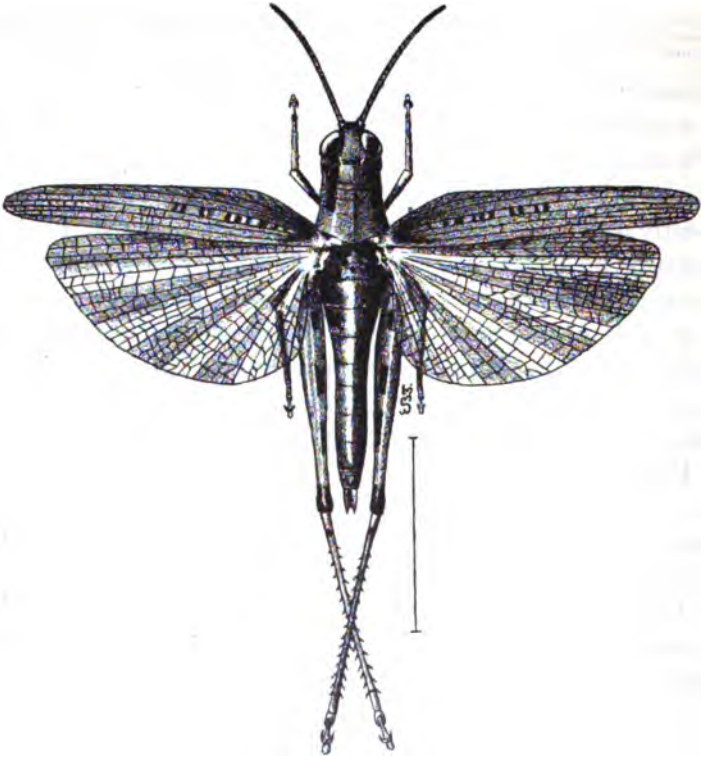


Fig. 122.—*Melanoplus femur-rubrum*, female. Original.

into the anteriorly tumid vertical lateral lobes, the disk generally darker than the lower portion of the lateral lobes, sometimes irregularly marked with luteous, the upper part of the lateral lobes crossed by a broad piceous band on the prozona, the lower portion more or less closely copying the

coloring of the face but usually a little darker; median carina slight, percurrent, a little less distinct on the prozona than on the metazona. Prosternal spine rather large, appressed-cylindrical, very blunt, often mesially constricted a little, feebly retrorse. Tegmina almost invariably surpassing, sometimes but slightly, more often considerably, the hind femora, of moderate breadth, distinctly though very gradually tapering, browish fuscous, sometimes immaculate, sometimes sprinkled with fuscous dots of greater or less depth and distinctness throughout the greater part of the discoidal area, but rarely to any considerable extent or conspicuousness beyond the middle; wings moderately broad, hyaline, glistening with fuscous veins and cross-veins darkest apically and anteriorly. Thoracic pleura piceous or blackish fuscous, the metathoracic episterna with a mesial streak of flavous of greater or less clarity. Fore and middle femora distinctly but not greatly tumid in the male; hind femora olivaceo-testaceous, more or less heavily and very variably obscured or clouded with fuscous, the fuscous coloring generally confined to the upper half, and above generally concentrated in two fasciæ, which sometimes extend partly in an oblique direction on the outer face, but generally in a very obscure fashion, if at all, while the whole under surface and at least the basal half of the inner surface is more or less impure flavous, sometimes deepening, especially beneath, to ferruginous or even carmine; hind tibiæ normally red, sometimes with a slight fuscous patellar spot, occasionally more or less tinged with yellowish, very rarely pale green with a yellowish tinge, the spines black nearly to their base, ten to thirteen, usually eleven, in number in the outer series.

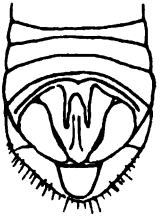


Fig. 121.—*Melanoplus femur-rubrum*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 121.

Length of body, male, 23.5 mm., female, 24.5 mm.; an-

tennæ, male, 10 mm., female, 8.5 mm.; tegmina, male, 21.5 mm., female, 19.75 mm.; hind femora, male, 13 mm., female, 14.25 mm.

This is our most common locust, found everywhere, and usually in very large numbers. If favored by dry summers this insect becomes very destructive, in fact it is controlled greatly by climatic conditions and parasites. It prefers low ground, cultivated fields and places abounding in rank and tender vegetation. This is the reason why dry hillsides are free of its presence, while lower meadows near by may be swarming with multitudes. The female is illustrated in Fig. 122.

Melanoplus angustipennis Dodge.

Of medium size, dark fuscous, head prominent, plumbeo- or ferrugineo-testaceous, often mottled with fuscous, above much infuscated, except at the margin of the eyes, and with a post-ocular piceous band; vertex gently tumid, slightly excavated above the pronotum; fastigium strongly declivent, distinctly (male) or feebly (female) sulcate throughout; frontal costa equal, percurrent, as broad as the interspace between the eyes, faintly sulcate at and below the ocellus, biseriately punctate; eyes moderately large and prominent. Pronotum dark fuscous, lighter on the lateral lobes, with a sub-luteous median streak, bordering a broad postocular piceous band on the prozona; disk feebly enlarging posteriorly, very broadly convex, passing into the vertical lateral lobes by a roundly angulated shoulder, forming tolerably distinct lateral carinæ on the posterior half of the pronotum; median carina distinct on the metazona, obsolete (male) or sub-obsolete (female) on the prozona. Prosternal spine not very long, erect, conico-cylindrical, blunt. Tegmina reaching or slightly surpassing the tips of the hind femora, slender, tapering, brownish-fuscous, immaculate or with very obscure and feeble maculations along the middle line. Fore and middle femora distinctly but not greatly tumid

in the male; hind femora olivaceo-luteous, more or less infumated or infuscated excepting below, the inner half of the upper face feebly bifasciate with fuscous, and the geniculations more or less infuscated; hind tibiæ glaucous, apically growing feebly lutescent, the spines black apically, pallid basally, nine to twelve in number in the outer series.

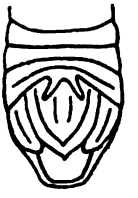


Fig. 123.—*Melanoplus angustipennis*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 123.

Length of body, male, 20 mm., female, 22.5 mm.; antennæ, male, 10 mm., female, 8.75 mm.; tegmina, male, 16 mm., female, 16.5 mm.; hind femora, male, 11.5 mm., female, 13 mm.

A few specimens of this species have been found in Minnesota. It seems to be uncommon, at least in regions visited by the writer.

Melanoplus impiger Scudder.

Of moderately large size, above rather light brownish fuscous with a ferruginous tinge, below luteo-testaceous. Head slightly prominent, dull luteo-testaceous, often punctate with olivaceous, with a post-ocular piceous band, and above much mottled or marmorate with fuscous; vertex gently tumid, considerably elevated above the level of the pronotum; fastigium steeply declivent, shallowly and broadly sulcate; frontal costa percurrent (male) or scarcely percurrent (female), feebly contracted above but otherwise sub-equal, as broad as the interspace between the eyes, punctate throughout; eyes rather large, not very prominent. Pronotum subequal, feebly enlarging posteriorly, with a very broad post-ocular piceous band, occasionally maculate, especially in the female, rarely surpassing the prozona and broadening and decidedly weakening on the metazona: disk very broadly convex, passing by a blunt shoulder nowhere

forming distinct lateral carinæ, into the vertical, anteriorly feebly tumid, lateral lobes; median carina distinct on the

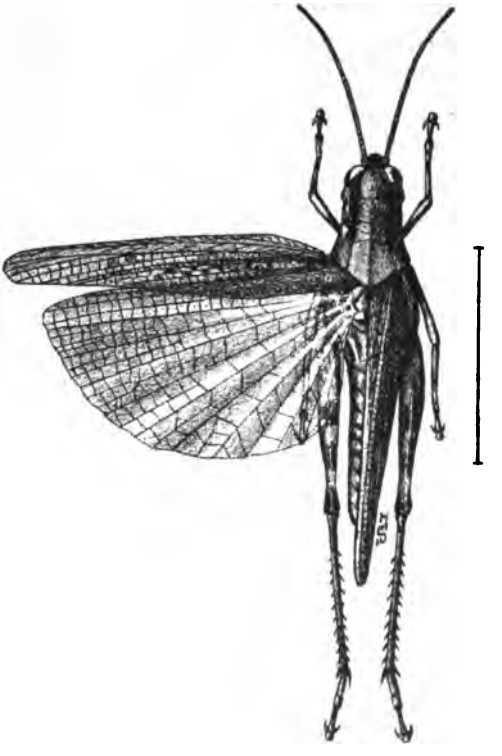


Fig. 125.—*Melanoplus impiger*, female. Original.

metazona, sub-obsolete on the prozona, sometimes wholly obsolete between the sulci. Prosternal spine conical, bluntly pointed (male) or appressed-cylindrical, very blunt (female), moderately long, erect. Tegmina surpassing considerably the hind femora, of normal breadth, feebly tapering, brownish fuscous, usually with very distinct and prominent maculation of quadrate blackish spots, interrupting a median luteous or pallid stripe on the basal half, becoming a sprinkling of blackish dots beyond, sometimes found also more or less obscurely in the other areas. Fore and middle legs only a little tumid in the male, luteo-testaceous flecked with fuscous; hind fem-

ora luteo-testaceous, twice barred above with blackish fuscous besides a basal spot, and more or less deeply infuscated geniculation, the bars liable on the middle of the outer face to fuse more or less completely into a median stripe, which

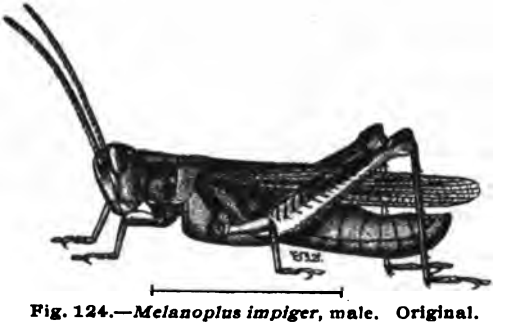


Fig. 124.—*Melanoplus impiger*, male. Original.

sometimes suffuses the whole face; lower face sometimes feebly roseate; hind tibiæ glaucous, occasionally feebly infuscated, the base and tip feebly lutescent, with a narrow post-basal fusco-glaucous annulus, the spines rather short, black beyond their pallid bases, ten to eleven in number in the outer series. Both sexes are shown in Figs. 124 and 125.

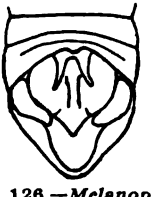


Fig. 126.—*Melanoplus impiger*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 126.

Length of body, male, 26.5 mm., female, 27 mm.; antennæ, male, 11 mm., female, 10.5 mm.; tegmina, male, 22 mm., female, 21 mm.; hind femora, male, 15.5 mm., female, 16 mm.

This insect has only been found upon Gray Cloud Island. It was mature as early as July 4, and proved quite destructive to garden plants.

Melanoplus minor Scudder.

Of medium size, dark brownish-fuscous, often with a ferruginous tinge, especially on the disk of the pronotum, luteous beneath. Head very feebly prominent, testaceous, ob-

scurely mottled with fuscous at least above, where there is generally a broad median blackish stripe and a post-ocular piceous band; vertex gently tumid, scarcely elevated above the pronotum; fastigium steeply declivent, narrow, equal, deeply (male) or shallowly (female) sulcate, the lateral margins sharp; frontal costa percurrent; eyes moderately large, a little prominent. Pronotum short, distinctly but not greatly expanding on the metazona, the post-ocular stripe of the lateral lobes extending over the prozona, broader and more distinct than on the head, the disk very broadly convex, passing into the sub-vertical lateral lobes by a distinct but always rounded shoulder nowhere forming lateral carinæ; median carina slight, scarcely less distinct on the prozona than on the metazona, cut only by the principal sulcus. Prosternal spine not very long, conico-cylindrical, more or less appressed, sub-erect. Tegmina reaching about to the tips of the hind femora, sometimes a little short of, sometimes surpassing them, rather slender and sub-equal, brownish fuscous, more or less distinctly but never heavily maculate with fuscous along the discoidal area. Fore and middle femora a little tumid in the male; hind femora luteo-testaceous, outside (excepting below) more or less deeply infuscated, the infuscation sometimes consisting of more or less well marked, very oblique, dusky fasciations, which also cross the upper face, the lower face generally dull orange; hind tibiæ very variable but generally nearly uniform in color, pale red or glaucous being the prevailing color, but they are sometimes plumbeous or yellowish; spines black tipped, ten to twelve, usually eleven, in number in the outer series.

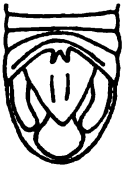


Fig. 127.—*Melanoplus minor*, tip of male abdomen. Original.

Extremity of male abdomen as shown in Fig. 127.

Length of body, male. 19 mm., female, 24 mm.; antennæ, male 8 mm., female, 9 mm.; tegmina, male, 14 mm., female, 16.5 mm.; hind femora, male, 11.25 mm., female, 13 mm.

A number of this species occurred with *spretus* during the local outbreak of the Rocky-Mountain Locust in Otter Tail county in 1889.

Melanoplus luridus Dodge.

Rather small in size, brownish fuscous, more or less ferruginous. Head not at all prominent, dull pallid testaceous, feebly flecked with fuscous, above with widening dull fuscous stripes and a narrow post-ocular band; vertex gently tumid, slightly or not at all elevated above the pronotum; fastigium steeply declivent, plane, with well elevated and rounded lateral margins; frontal costa just failing to reach the clypeus, subequal, sulcate at and below the ocellus, biseriately

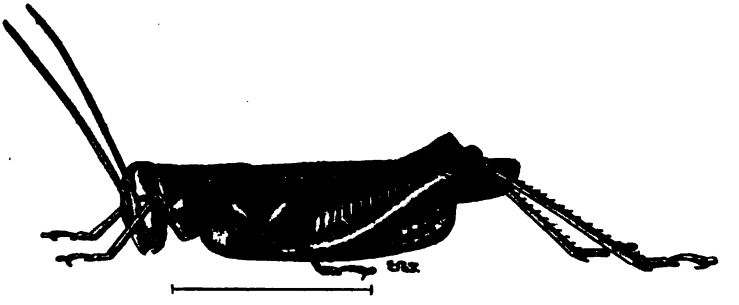


Fig. 128 —*Melanoplus luridus*, male. Original.

punctate above; eyes of moderate size, not prominent. Pronotum sub-equal, feebly and gradually enlarging posteriorly, the disk nearly plane, passing by distinct but abruptly rounded shoulders forming sub-obsolete lateral carinæ into the vertical lateral lobes, which have only an obscure, rarely a distinct, dark post-ocular band, always limited to the prozona; median carina percurrent but blunt and a little obscure on the prozona. Prosternal spine short, conical, blunt, erect, in the female a little appressed. Tegmina reaching or a little surpassing the tips of the hind femora, moderatly narrow, very gently tapering, brownish-fuscous, either scarcely or distinctly though feebly maculate in the proximal part of the discoidal area. Fore and middle femora tumescent in the male; hind femora long and slender,

luteo-testaceous, above rather broadly bi-fasciate with blackish fuscous, often confluent along the middle of the outer face and then more or less suffusing the whole face excepting below, which with the under surface is dull luteous, occasionally tinged more or less distinctly with orange, the sides of the geniculation almost wholly fuscous; hind tibiæ red, rarely with a very narrow, basal, fuscous annulus, the apical half of the spines black, ten to twelve in number in the outer series. Extremity of male abdomen as shown in Fig. 129.

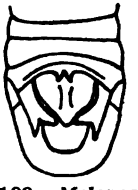


Fig. 129.—*Melanoplus luridus*, tip of male abdomen, Original.

Length of body, male, 19 mm., female, 27 mm.; antennæ, male, 8.5 mm., female, 9.5 mm.; tegmina; male, 14 mm., female, 17 mm.; hind femora, male, 10.75 mm., female, 13.5 mm.

Many specimens were captured near the Experiment Station at St. Anthony Park; a male is shown in Fig. 128.

Melanoplus differentialis Uhler.

The largest of our species of Melanopli and heavy bodied; excepting the hind legs and the lateral lobes of the pronotum, the general color is nearly uniform, brownish testaceous. The head has sometimes a pair of dusky, divergent stripes, passing from the posterior corners of the fastigium backward across the vertex and, when these are present, there are often other but irregular streaks of similar tint on the genæ and clouds over parts of the face; the vertex is gently arched, more gently in the female than in the male, with a broad interval between the eyes, the fastigium broadly and not very deeply impressed; frontal costa broad but narrower than the interspace between the eyes, percurrent, equal except for a slight ex-

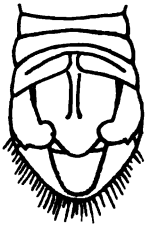


Fig. 130.—*Melanoplus differentialis*, tip of male abdomen. Original.

pansion below, broadly and shallowly sulcate below the ocellus, punctate; eyes moderately prominent, short, not a great deal longer than broad. Pronotum sub-equal, the metazona expanding somewhat, the disk of the prozona sometimes very feebly tumid, the median carina distinct and sharp on the metazona, less prominent but distinct on anterior half of the prozona, still less distinct between the sulci. Prosternal spine rather long, conical as seen from the side, bluntly cylindrical as seen from the front, a very little retrorse. Tegmina at least reaching (female) or distinctly surpassing (male) the hind femora, absolutely free from maculation, the narrowest apical portion about half as

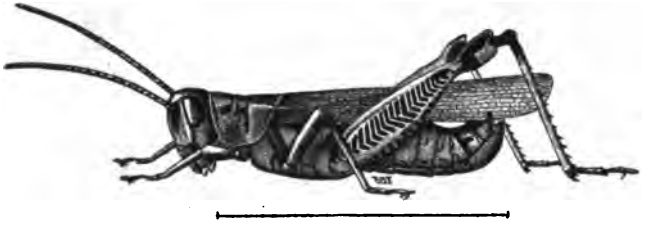


Fig. 131.—*Melanoplus differentialis*, male. Original.

broad as the broadest sub-basal portion. Fore and middle femora of male heavily bullate, the hind femora stout and rather short, moderately tumid, generally fulvo-testaceous, sometimes flavo-testaceous beneath, the outer face with alternate, fulvo-testaceous and black, narrow, equal fish-bone markings, the black rarely interrupted in the middle, the upper inner face with small basal and large median and post-median black patches, the genicular arc black on both inner and outer sides; hind tibiæ yellow or fulvous, with a post-basal narrow black annulus, the spines black to their very base, ten to eleven, rarely twelve, in number in the outerseries. Extremity of male abdomen as shown in Fig. 130, and the sexes in Figs. 131 and 132.

Length of body, male, 39 mm., female, 41 mm.; antennæ, male, 18 mm., female, 16 mm.; tegmina, male, 32 mm., female, 34.5 mm.; hind femora, male, 20 mm., female,

23 mm. Some specimens are much smaller.

This locust is but rarely found in Minnesota; if found it is only of local occurrence.

Fig. 132.—*Melanoplus differential.s*, female. Original.

Melanoplus bivittatus Say.

Varying in general groundcolor from fusco-testaceous to very dark brownish fuscous, striped with fulvo- or pallid-testaceous. Head flavo-testaceous, more or less infuscated, the summit with a broad, median, widening, blackish-fuscous stripe, which extends backward from the front of the fastigium but avoids the eye; vertex gently tumid, the fastigium broadly, equally and very shallowly sulcate; frontal costa broad, sub-equal, with roundish margins, feebly sulcate at and below the ocellus, feebly punctate laterally. Pronotum enlarging a little from in front backward, more feebly in the male than in the female; the median carina slight but distinct throughout. Tegmina attaining, or a little surpassing the hind femora, generally longer in the male than in the female, brownish or blackish fuscous, the anal vein marked by a slender flavous stripe, the discoidal area not darker than the rest, generally almost clear but frequently with faint and delicate mottling. Fore and middle femora ferruginous, more or less heavily infuscated above; hind femora rather long and moderately stout, ferrugineo-testaceous, the outer and generally the inner faces black above, flavo-testaceous below, the inner half of the upper face thrice very broadly banded with black, the genicular

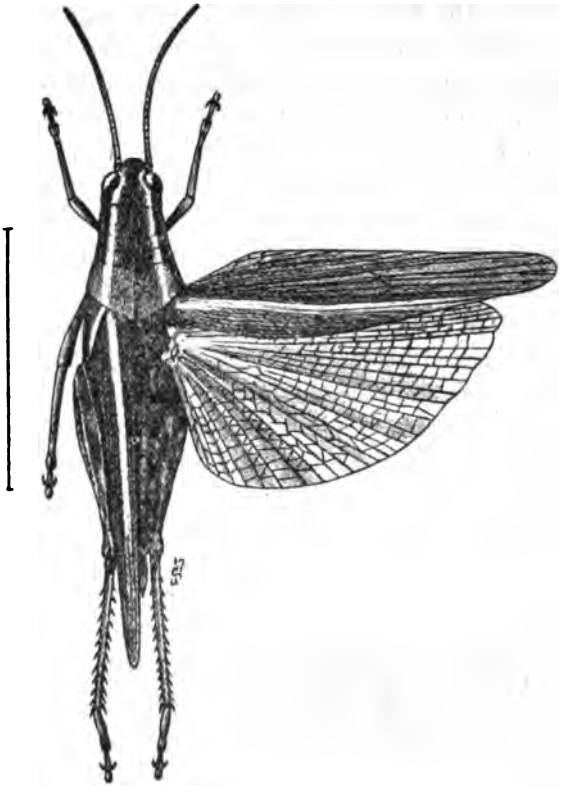


Fig. 133.—*Melanoplus bivittatus*, female. Original.

arc and a basal transverse stripe across the lower genicular lobe black on both sides; hind tibiæ passing more or less gradually, at varying points but generally near the middle, from purplish at the base to greenish yellow (very rarely red

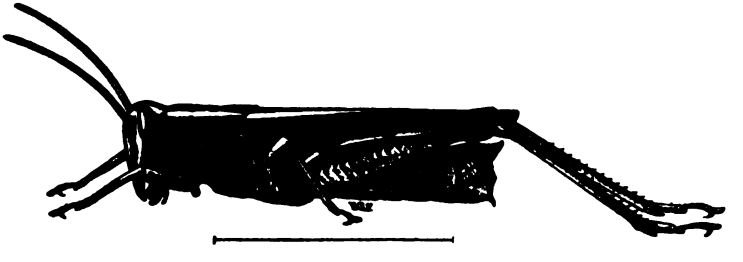


Fig. 134.—*Melanoplus bivittatus*, female. Original.

or reddish) at the tip, the patella of the lighter color, followed in lighter examples by a narrow black annulus, the spines black almost or quite to their base, ten to thirteen in number in the outer series. The adult insect and the pupa is shown in Figs. 133, 134 and 135.

Length of body, male, 27 mm., female, 37 mm.; antennæ, male, 14.75 mm., female, 13 mm.; tegmina, male, 20.5 mm., female, 26.5 mm.; hind femora, male, 15 mm., female, 20 mm.

This is a very common and destructive species. It is found in all parts of the state, preferring bottom lands, edges of cultivated fields and other places with a rank vegetation. It sometimes becomes very numerous, and spreads over cultivated fields, where it causes great damage, feeding upon grasses and grains. Though appearing in the winged state as early as the tenth of July, it deposits no eggs until late in August. Any compact soil, free of roots, and well

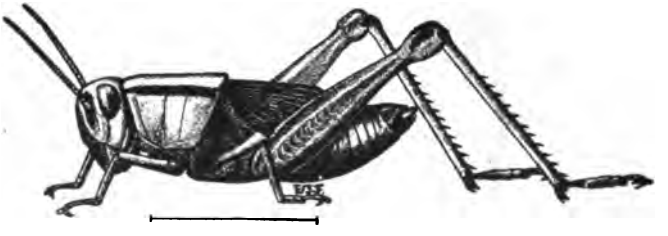


Fig. 135.—*Melanoplus bivittatus*, pupa. Original

drained, is chosen for this purpose. As many as eighty eggs have been counted in a single egg-pod, though the usual number varies from 54 to 70. The illustrations shown in the chapter giving the anatomical features of a locust were made from this species.

Melanoplus punctulatus Uhler.

Dark brownish-fuscous much mottled with blackish and often tinged with dull olivaceous; beneath ferrugineo-testaceous. Head varying from pale dull olivaceous to ferrugineo-testaceous, irregularly mottled with widening median stripe of the same upon the summit; vertex tumid; fastigium rap-

idly declivent, sulcate throughout, the margins much raised between the eyes, which are separated by a space less than the width of the frontal costa; the latter prominent above, moderate in breadth, sub-equal, sulcate below the ocellus, sparsely punctate throughout, each point marked by a dark olivaceous dot; eyes large and in the male very prominent, in both sexes much longer than the infra-ocular portion of the genæ. Pronotum sub-equal, widening a little at the metazona in the female, slightly flaring in front to receive the head, especially in the male, varying from luteo-testaceous to brownish fuscous, often much flecked and punctate with black or blackish fuscous, the lateral lobes more heavily marked above with black on the prozona, forming generally a broken or maculate band. Tegmina somewhat surpassing the hind femora, very gradually tapering to a well-rounded apex, fusco-testaceous, sprinkled with moderately large roundish or quadrate fuscous spots. Fore and middle femora luteo- or olivaceo-testaceous, heavily flecked with black, showing a tendency to form a triple belting; hind femora similar, the black forming moderately narrow basal, premedian, post-median and apical belts, which do not touch the coralline under and inner surfaces, except the latter in a partial way; hind tibiæ dull red, with a post-basal obscure flavous annulus, before which they are sometimes blackened, and beyond which, above and on the sides, often flecked or suffused with plumbeo-fuscous, the serial space between the spines often dull luteous, the whole pilose; spines black nearly or quite to their base, except on the inner side, ten to twelve in number in the outer series, none arising very near the base of the tibiæ. Extremity of the male abdomen as shown in Fig. 136.

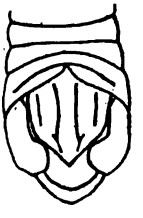


Fig. 136.—*Melanoplus punctulatus*, tip of male abdomen. Original.

Length of body, male, 21 mm., female, 28 mm.; antennæ, male, 14.5 mm., female, 12 mm.; tegmina, male, 17 mm., female, 18.5 mm.; hind femora, male, 10.5 mm., female, 12 mm.

Only a single specimen was found among the trees on Gray Cloud Island. The insect seems to be quite local. It has been found elsewhere in tamarack swamps, on pine and oak trees, and in cranberry bogs.

Melanoplus fasciatus (*borealis* Scud.).*

Rather small, dark fusco-plumbeous above, dark clay yellow below. Head not prominent, dull plumbeous, flecked with griseous, above very dark fuscous with a broad post-ocular piceous band; vertex moderately tumid, distinctly elevated above the pronotum, the interspace between the eyes as broad (male) or nearly half as broad again (female) as the basal antennal joint; fastigium strongly declivent, shallowly depressed, but with distinct and somewhat abrupt though rounded bounding walls, which diverge a very little in front of the eyes and then converge; frontal costa as broad as the interspace between the eyes, scarcely contracted above where its face is plain (male) or feebly tumid (female), at and below the ocellus rather narrowly sulcate, deeper in the male than in the female, percurrent, punctate, eyes rather small, not prominent, longer than the infra-ocular portion of the genæ; antennæ ferruginous, growing lutescent toward the base, dusky toward the tip, nearly or quite as long (male) or about two-thirds as long (female) as the hind femora. Pronotum sub-equal, feebly expanding posteriorly, especially in the female, the disk plano-convex, separated by a well-rounded but distinct shoulder from the vertical lateral lobes, brownish fuscous, sometimes fusco-testaceous, and then generally punctate with ferruginous, the upper part of the lateral lobes with a broad piceous band crossing the prozona and sometimes continued as a feeble dusky cloud on the metazona; front border truncate, hind border broadly obtuse angulate, the angle rounded; median carina distinct only on the metazona and at the front of the prozona, elsewhere obsolete or sub-obsolete; prozona feebly longitudinal

*Discovered since printing table of *Melanopli*.

(male) or feebly transverse (female), a very little longer than the minutely rugulose metazona. Prosternal spine short, stout, blunt, conical, erect; interspace between mesosternal lobes nearly half as long again as broad (male) or considerably transverse but shorter than the lobes (female). Tegmina either abbreviated, being one and a half or two and a half times as long as the pronotum, and not nearly reaching the tips of the hind femora, tapering considerably beyond the basal expansion, sub-lanceolate and bluntly sub-acuminate (form *curtus*), or far surpassing the hind femora, broad and sub-equal, very feebly tapering in the apical half, and well rounded at tip (form *volaticus*), wholly brownish-fuscous, or cinereo-fuscous, occasionally maculate to a greater or less degree, but generally slightly in the discoidal area, the anal area sometimes more cinereous than the rest, especially apically; wings in both forms hyaline, with a scarcely perceptible yellowish tint, more or less densely but always feebly infumated at the tip, the veins and cross-veins of the apical half blackish fuscous. Hind femora relatively longer in the female than in the male, dull luteo-testaceous, black at apex and at extreme base, and bifasciate with black or blackish fuscous more or less broadly and obliquely, rarely transversely, the whole often confused and more or less blended on the outer face; beneath pale or dull reddish, hind tibiæ red, usually growing paler toward the base and sometimes almost wholly pale greenish luteous, feebly reddening apically, the base generally pale or at least paler, with a small fuscous patellar spot, the spines black except at extreme base, nine to twelve, generally eleven, in number in the outer series.

Fig. 136½.—*Melanoplus fasciatus*, tip of male abdomen. Original.

Extremity of male abdomen illustrated in Fig. 136½.

Only the short-winged form has been found in St. Anthony Park.

Measurement.—Length of body, male, 18.5 mm., female,

22 mm.; antennæ, male, 10 mm., female, 8 mm.; tegmina, male, 10 mm., female, 9.75 mm.; hind femora, male, 10 mm., female, 11.75 mm.

GENUS *Phœtaliotes** Scudder.

Body elongate, rather slender, a little compressed, very feebly pilose, including faintly the tegmina and legs. Head large, full, prominent, relatively elongate, nearly half as long again as the prozona, the space behind the eyes fully half as long as the breadth of the eyes, the genæ a little tumescent, the head apart from the eyes slightly broader than the pronotum; vertex prominent and well arched both longitudially and transversly; face a little oblique; eyes rounded, broad oval, moderately prominent, sub-truncate anteriorly, moderately distant, somewhat farther apart than the greatest width of the frontal costa; fastigium very faintly sulcate, almost plane; frontal costa prominent, markedly narrower above than below the ocellus; antennæ slender, moderately long, but shorter than the hind femora, though fully twice as long as the pronotum. Pronotum of moderate length, faintly sub-sellate but otherwise equal, feebly flaring in front to receive the head; disk rounded sub-tectate, with broadly rounded very indistinct lateral carinæ, and a sharp, equal, and percurrent median carina; prozona longitudinal, nearly half as long again as the metazona, with indistinct transverse sulci; front margin sub-truncate, hind margin extremely obtuse-angulate. Prosternal spine rather large, erect, conical, blunt. Tegmina either abbreviate, broad lanceolate, acuminate, attingent, slightly longer than the pronotum, or fully developed, surpassing the hind femora, rather broad and equal, well rounded at tip, hardly tapering in the distal half. Hind femora long and slender, hind tibiæ glaucous, with eleven to thirteen spines in the outer series. Abdomen compressed, recurved in the male, the sub-genital plate narrow and long, with lateral margins ampliate at

*A roamer.

Fig. 137.—*Phœtaliotes nebrascensis volucris*. male. Original.

base; furcula delicately developed; cerci compressed styliform, rather small; ovipositor of female normally excerted.

This genus is closely allied to *Melanoplus*, from which it differs by its large tumid head and sub-sellate equal pronotum.

Phœtaliotes nebrascensis volucris Scudder.

This is the short winged form, the only one found thus far in Minnesota. Fusco-testaceous, flavous beneath. Head flavo-testaceous, in fresh specimens more or less fusco-olivaceous, much infuscated above, with a broad piceous post-ocular band, and often with a pair of divergent fuscous or ferrugineous stripes on the summit; vertex very tumid, distinctly elevated above the level of the pronotum; eyes moderately large, rather prominent. The male of this curious insect is shown in Fig. 137.

Measurements.—Length of body, male, 22 mm., female, 23 mm.; antennæ, male, 9.5 mm., female, 7 mm.; tegmina, male, 6 mm., female, 6.5 mm.; hind femora, male and female, 11.75 mm.

FAMILY VI. *Locustidæ*.

LONG-HORNED GRASSHOPPERS AND KATYDIDS.

All the members of this family are readily recognized, differing very greatly from the true locusts or short-horned grasshoppers (*Acrididæ*) by their long and slender antennæ, which are longer than the body. From the next family, the *Gryllidæ*, which possess also slender and long antennæ, they differ by the form of their ovipositor, which is compressed and sword-like. *Locustidæ* have four-jointed tarsi; the musical apparatus of the male, situated at the base of the

wing-covers, is smaller than in crickets; at rest the tegmina, excepting basal areas, are vertical.

Prof. Scudder gives the following sub-families of *Locustidæ*, four of which occur in Minnesota.

SUB-FAMILIES OF LOCUSTIDÆ.

A. Body generally winged, tarsi more or less depressed.
- b. Fore tibiæ furnished with foramina near the base; male tegmina, when present, furnished with a tympanum.
  - c. First two joints of tarsi smooth laterally; hind tibiæ with an apical spine on each side. *Phaneropterinæ*.
  - cc. First two joints of tarsi longitudinally sulcate laterally; hind tibiæ with an apical spine on outer side only or on neither.
    - d. Fore tibiæ without apical spines.
      - e. Fastigium of vertex short, crowded by the prominent antennal scrobes; pronotum crossed by two distinct transverse sulci. *Pseudophyllinæ*.
      - ee. Fastigium of vertex extended and free from the not prominent antennal scrobes; pronotum without, or with only one, transverse sulcus. *Conocephalinæ*.
    - dd. Fore tibiæ with an apical spine on the outer side. (Body generally sub-apterous). *Decticinæ*.
- bb. Fore tibiæ without foramina near the base; male tegmina without a tympanum.....*Gryllacrinæ*.

AA. Body apterous; tarsi distinctly compressed. *Stenopelmatinæ*.

The first sub-family, *Phaneropterinæ*, contains three groups of insects found in Minnesota.

a. Fore and middle tibiæ sulcate or plane above, but acutely margined, the outer margin spinulose or unarmed.
   b. Fastigium of vertex scarcely deflexed, acuminate, no broader than the first antennal joint.....*Scudderiæ*.
   bb. Fastigium of vertex deflexed, obtuse, much broader than the first antennal joint; metasternum truncate or with rounded lobes.....*Amblycoryphæ*.
aa. Fore and middle tibiæ smooth above, without angular margin, generally unarmed above; metasternum with elongated lobes.....*Microcentra*.

Prof. Blatchley gives the following key to genera of *Phaneropterinæ:*

a. Wing-covers of equal breadth throughout; supra-anal plate of male with a long decurved spine which is notched at the end.....1. *Scudderia*.
aa. Wing-covers widest in the middle; supra-anal plate of male not as above.
   b. Hind femora but little if any shorter than wing-covers; ovipositor well developed, curved gradually upwards.....2. *Amblycorypha*.
   bb. Hind femora much shorter than the wing-covers; ovipositor very short, turned abruptly upwards. 3. *Microcentrum*.

The four species of *Scudderia* described in the text are distinguished as follows:

a. Length of posterior femora 28 or more millimeters.
   b. Notch of supra-anal spine of male square with a slight median tooth, almost as wide as the middle of the upturned sub-anal spine; the lateral processes slender and compressed....*curvicauda* DeGeer.
   bb. Notch of supra-anal spine of male acute and much narrower than the middle of the upcurved sub-anal spine; the lateral processes (at side of notch) broadly rounded with the lower margin thinner. *furculata* Brunner.

aa. Length of posterior femora 22 or 23 mm.
furcata Brunner.

aaa. Length of posterior femora less than 20 mm.
angustifolia Harris.

GENUS *Scudderia* Stål (1873).

Head oval; eyes round and protruding, vertex pinched; antennæ longer than the wings, first joint cylindrical, stout, second joint smaller, remaining joints hair-like. Thorax longer than broad, narrower in front than behind; lateral carinæ sharply defined. Wing-covers shorter than the wings and of nearly equal width throughout, apex rounded. Hind legs very long and slender. Male with the anal plates provided with two curved spines, the one from the supra-anal plate curved downward and notched at the end, and the one from the sub-anal curving upwards and grooved above. Female with the ovipositor short, broad, flat and turned upwards, with the apical portion very finely serrate.

Four species have been found in Minnesota, but it is very likely that a fifth will be detected upon a closer search. They are all very similar, but can readily be distinguished by studying the structure of the anal plates of the males.

Scudderia curvicauda DeGeer.

THE NARROW-WINGED KATYDID.

This is one of the most common of our Katydids, found in many places during August and until cold weather. It is especially common among low bushes in damp places. When approached it flies readily in a zigzag, noiseless manner for a long distance to another clump of weeds, or to the lower branches of an oak, a tree in which it delights to dwell.

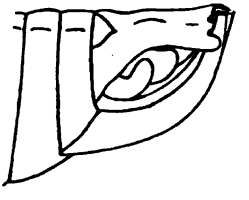


Fig 188.—*Scudderia curvicauda*, tip of male abdomen. Enlarged. Original.

Wing-covers, legs and thorax pale green; head and under-side of body paler; pronotum

much longer than broad, narrower in front than behind, and with a yellow line along the lateral carinæ. The notch of the supra-anal spine is square, with a minute median tooth, the lateral parts of notch compressed. Posterior femora very slender, armed beneath on inner carina with three or four minute spines. The tip of male abdomen is shown in Fig. 138.

The eggs of this species, as well as of several others, are laid one or more, in the edges of leaves, between the upper and lower cuticles, in the same manner as a saw-fly deposits eggs. The eggs, are loosely inserted in these pockets made by the ovipositor of the mother, and as they swell in coming in contact with the ruptured tissues of the plant they are held tightly in place.

Measurements.—Length of body, 22-25 mm.: wing-covers, 33-37 mm.; posterior femora, 25-27 mm.

Scudderia furculata Brunner.

Somewhat larger, very much like *curvicauda*, but readily distinguished from it by the notch of the supra-anal spine of the male, which is acute, and by the sides of the notch being rounded, flattened at the end and compressed beneath into a small flat process. The female is almost like that of *curvicauda;* it lacks, however, the black color at the basal fold of the ovipositor. The general color is the same, but the yellow carinal line of the pronotum is less distinct or wholly wanting in *furculata*, and the apical third of wings

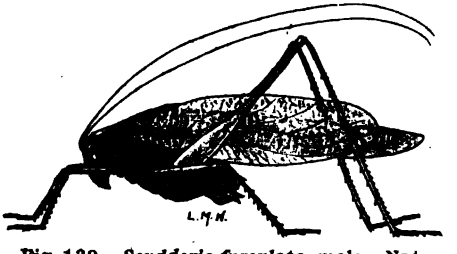


Fig. 189.—*Scudderia furculata*, male. Natural size. Original.

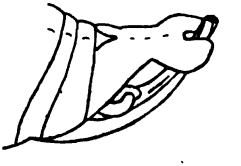


Fig. 140.—*Scudderia furculata*, tip of male abdomen. Enlarged. Original.

is usually a transparent reddish-brown. The wing-covers of the latter are broader, and the posterior femora proportionally a little shorter. The male is shown in Fig. 139 and the tip of the male abdomen in 140.

Measurements.—Male, length of body, 20-23 mm., wing-covers, 34-38 mm., posterior femora, 24-30 mm. Female: Length of body, 22 mm.; wing-covers, 34 mm.; posterior femora, 27 mm.

This species, though not very uncommon, is not observed as frequently as others; it seems to prefer the borders of marshes and tamarack swamps, where it can be found during the month of August.

Scudderia furcata Brunner.

THE FORKED-TAILED KATYDID.

Grass green; wing-covers narrower and of equal width throughout, apex rounded; lateral carina of pronotum without trace of a yellow line. The anterior margin of the pronotum is but slightly narrower than the posterior, whereas in the two preceding species the difference in width is plainly perceptible. The notch of the supra-anal spine of the male is very deep, and the lateral pieces very much swollen. The tip of male abdomen is shown in Fig. 141.

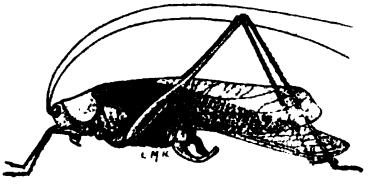


Fig. 142.—*Scudderia furcata*, male. Natural size. Original.

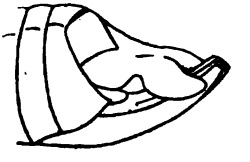


Fig. 141.—*Scudderia furcata*, tip of male abdomen. Enlarged. Original.

Measurements.—Male: Length of body, 16 mm.; wing-covers, 31 mm.; posterior femora, 23 mm.; pronotum, 5 mm.; width of wing-covers, 6 mm. Female: Length of body, 20 mm.; wing-covers, 30 mm.; posterior femora, 22 mm.; ovipositor, 5 mm.

The Forked-tailed Katydid, both sexes of which are shown in Figs. 142 and 143, is one of the smallest and at the same time most common of the katydids; it frequents thickets along fences, coarse grasses and weeds. Prof. Riley gives the following account of the egg-laying habits of *furcata:* "The female stations herself firmly by the middle and hind legs on twigs or leaves contiguous to the one selected to receive the eggs. This leaf is then grasped by the front feet and held in a vertical position, while the edge is slightly gnawed or pared off by the jaws to facilitate the entrance of the point of the ovipositor. When this is done the abdomen is curved under and brought forward, and the ovipositor is seized on its convex edge by the mandibles and maxillæ, which, with the aid of the palpi, guide the point to that portion of the leaf prepared to receive it. After gentle, but repeated efforts, the point of the instrument is finally inserted between the tissues of the leaf, and gradually pushed in to more than half its length. As soon as the cavity is formed, the egg is extruded, and passed slowly between the semi-transparent blades of the ovipositor. As the egg leaves the ovipositor the latter is gradually withdrawn, while the egg remains in the leaf, retained in its place probably by a viscid fluid that is exuded with it. As many as five of the eggs are sometimes deposited in one row in the same leaf, but more often they are single."

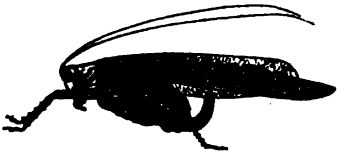


Fig. 143.—*Scudderia furcata*, female. Natural size. Original.

Scudderia angustifolia Harris.

THE NARROW-WINGED KATYDID.

In size, general appearance and structure of anal spines of male it is very similar to *furcata*, but may readily be known by its short posterior femora, and by its narrower wing-covers.

Measurements.—Male: Length of body, 14 mm.; of tegmina, 26 mm.; of posterior femora, 19 mm.; of pronotum, 4 mm.; width of tegmina, 5 mm. **Female:** Length of body, 19 mm.; of tegmina, 25 mm.; of ovipositor, 5.5 mm.

Prof. Scudder, who has so carefully studied the songs of most of our orthoptera, gives the following pleasing account of its song: "It is more noisy by night than by day; and the songs differ considerably at these two times. The day song is given only during sunshine, the other by night and in cloudy weather. I first noticed this while watching one of the little creatures close beside me; as a cloud passed over the sun he suddenly changed his note to one with which I was already familiar, but without knowing to what insect it belonged. At the same time all the individuals around me, whose similar day song I had heard, began to respond with the night cry; the cloud passed away, and the original note was resumed on all sides. Judging that they preferred the night song to that of the day, from their increased stridulation during the former period, I imitated the night song during sunshine, and obtained an immediate response in the same language. The experiment proved that the insects could hear as well as sing. The note by day is *b z r w i* and lasts for one-third of a second. The night song consists of a repetition, ordinarily eight times, of a note which sounds like *t c h w*. It is repeated at the rate of five times in three-quarters of a second, making each note half the length of the day note."

Scudderia pistillata Brunner.

This species also occurs in Minnesota. It is found late in summer in the same localities as *curvicauda*. It can be readly recognized by its relatively broad tegmina.

Apex of vertex concave; pronotum narrower in front than behind; wing-covers very broad, wider at the middle than at the base and apex, with radiating veins; anterior margin curved, inner margin quite straight, apex rounded;

Fig. 144.—*Scudderia pistillata*, male. Natural size. Original.

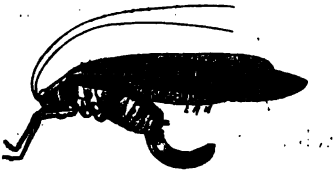


Fig. 145.—*Scudderia pistillata*, female. Natural size. Original.

supra-anal process notched at the apex, with rounded lobes; sub-anal process extending a little beyond the upper process.

Measurements.—Male: Length of body, 16-20 mm.; wing-covers, 29-31 mm.; posterior femora, 21-23 mm. Female: Length of body, 18-20 mm.; wing-covers, 27-30 mm.; posterior femora, 21-23 mm.

Both sexes are illustrated in Figs. 144 and 145.

GENUS *Amblycorypha* Stål. (1873).

Head with the vertex flat; eyes elliptical or oblong oval; antennæ thread-like, first joint large and thick, second joint but slightly smaller, thind joint slender. Wing-covers broad and rounded at the tip. Male with the supra-anal plate truncate; sub-anal plate short and broad at base, narrower at apex, with a deep triangular notch, each tip with a short blunt spine-like process. Female with a long, flat, curved ovipositor, deeply serrated towards the end.

Species in this genus can readily be recognized by the broad, oblong and rounded wing-covers.

At least two species are found in Minnesota.

a. Tegmina about 37 mm. in length; exceeding the tip of posterior femora.....*oblongifolia* DeGeer.

aa. Tegmina less than 30 mm. in length; sometimes reaching but not exceeding the tip of posterior femora.

b. Greatest breadth of tegmina contained less than three times in their length; ovipositor strongly curved.....*rotundifolia* Scudder.

bb. Greatest breadth of tegmina contained from 3¼ to 3½ times in their length; ovipositor but moderately curved.....*Uhleri* Brunner.

Amblycorypha rotundifolia Scudder.

ROUND-WINGED KATYDID.

Wing-covers oblong-oval, pale pea-green; body somewhat smaller; hind wings transparent, with the veins and

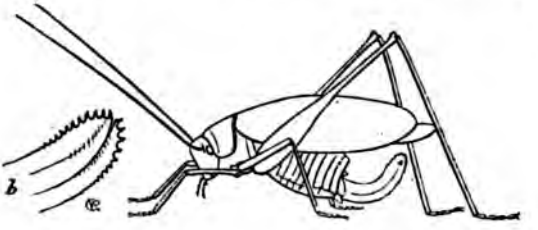


Fig. 146.—*Amblycorypha rotundifolia*, outline of female, with enlarged end of ovipositor (*b*). After Riley.

apical patch green; posterior femora with four or five small spines and reaching to the tip of the wing-covers; ovipositor strongly curved upwards and strongly serrated at the apical portion. The female is illustrated in Fig. 146.

Measurements.—Length of body, about 30 mm.; wing-covers, 27 mm.; posterior femora, 23 mm.

Amblycorypha oblongifolia DeGeer.

OBLONG LEAF-WINGED KATYDID.

Similar to *rotundifolia*, but longer and broader. The wing-covers extend beyond the posterior femora, and the an-

Fig. 147.—*Amblycorypha oblongifolia*, female. Natural size. Original.

terior portion of the thorax is considerably narrower than the posterior. Color pale pea-green, sometimes wholly rose-color. Lower carina of posterior femora with about ten strong teeth.

Measurements.—Length of body, 21 mm.; wing-covers, about 38 mm.; posterior femora, 30 mm.; expanse of wings, 75-85 mm.

Both species occur abundantly in Minnesota, frequenting bushes and tall weeds in low places. They are very similar, but the latter, besides being larger with longer wing-covers, has also the ovipositor less serrate and less curved. Fig. 147 shows the female insect.

Amblycorypha Uhleri Brunner.

This insect, quite common in Maryland, New Jersey and the District of Columbia, has also been found in Indiana, and a specimen in the collection of the writer is marked: Minnesota, Aug. 17. No locality is given, however.

Measurements.—Male: Length of body, 25 mm.; of tegmina, 42 mm.; of posterior femora, 22.5 mm.; of pronotum, 6 mm.; width of tegmina, 13 mm. Female: Length of body, 30 mm.; of tegmina, 46 mm.; of posterior femora, 24 mm.; of ovipositor, 5 mm.; width of tegmina, 14 mm.

GENUS *Microcentrum* Scudder (1862).

Size large. Wing-covers moderately expanded in the middle, much longer than the posterior femora, and with the outer border sloping off quite sharply, thus causing the tip to be more pointed than in *Amblycorypha*. Vertex much as in that genus, slightly furrowed. Eyes broadly oval, very prominent. Hind legs slender and very short, the femora but little more than half as long as the tegmina. Ovipositor very short, bent abruptly, bluntly pointed, and with the apical third finely serrate above. Anal plates of male not prolonged.

Microcentrum laurifolium Linn.

LARGER ANGULAR-WINGED KATYDID.

General color light grass green, the body yellowish-green, lighter beneath. Vertex quite broad, with the center hollowed out so as to form a shallow pit, which is more prominent in the male. The pronotum is about as broad as long, its anterior margin a little concave and usually possessing a slight median tooth, though this is sometimes obsolete, or is replaced with a shallow notch. The overlapping dorsal surface of the wing-covers form a sharp and prominent angle with the lateral portions, hence the common name "angular-winged."

This insect, very common in the southern states, has been found near Winona, but will very likely occur also elsewhere. It is sometimes attracted to the electric light. Wherever it occurs it is most commonly called "the Katydid," though the sounds produced by it are quite different, being something like the syllable "*tic*" repeated from eight

Fig. 148.—*Microcentrum laurifolium*, male. After Riley.

to twenty times at the rate of about four to the second. The grayish-brown eggs, long oval in shape, very flat, measuring 5.5x3 mm., are usually glued in double rows on the sides of tender twigs, or on the edge of leaves, which have been previously roughened with the jaws and otherwise prepared for a place of deposit. The two rows are contiguous

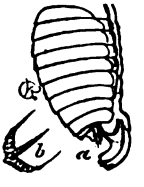


Fig. 149.—*Microcentrum laurifolium*; *a*, ovipositor, nat. size; *b*, tip of same, enlarged. After Riley.

and the eggs of one alternate with those of the other; those of the same row overlap about one-fourth of their length. They are deposited in September, and frequently attract the attention on account of their remarkable regularity. The three illustrations, Figs. 148, 149 and 150 show this insect.

The sub-family *Pseudophyllinæ* is represented by a single genus, *Cyrtophyllus*, Burm.

GENUS *Cyrtophyllus* Burmeister (1838).

It is doubtful whether this genus is found in Minnesota or not, but as it has been captured just south of the state

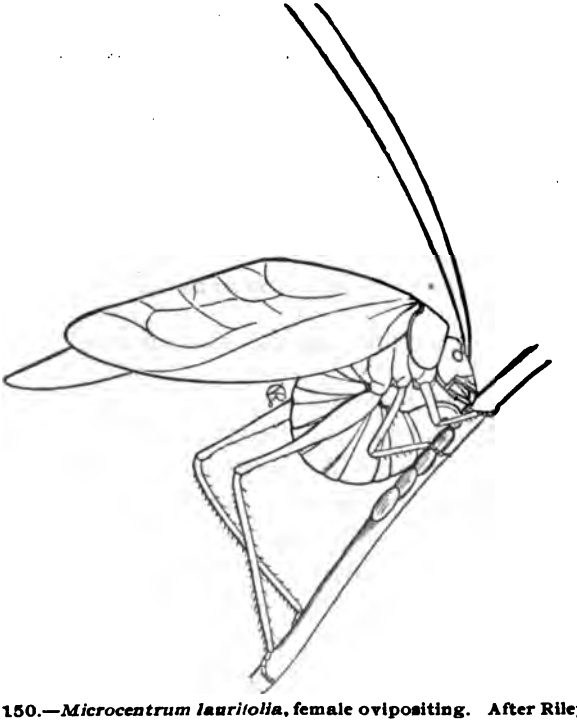


Fig. 150.—*Microcentrum laurifolia*, female ovipositing. After Riley.

the possibility of its occurrence is not excluded.

Head large and stout; eyes hemispherical and comparatively small, vertex spine-like; antennæ almost twice as

long as the wings; pronotum as broad as long on top with two transverse furrows; lateral carina well rounded, lobes of sides parallel, with angles acutely rounded; wings concave; wing-covers longer than the hind wings, a little more than twice as long as broad, and of almost equal width, with the apex obtusely rounded. Anterior pairs of legs long and rather stout, and well adapted for climbing; hind legs almost twice the length and also stout. Supra-anal plate longer than broad, and bluntly rounded at the tip; sub-anal plate of male very long, paddle-shaped, and grooved on the upper side; ovipositor of female quite long and curved upwards beyond the middle.

The members of this genus are at once distinguished from all other *Locustidæ* by the broad leaf-like form of the tegmina, which are longer than the wings, obtuse and rounded at the end, and concave or hollowed within. The "shrilling" organ of the male is brown in color with the central portion as transparent as glass, and is set in a strong half-oval frame.

Cyrtophyllus concavus Harris.

TRUE KATYDID. BROAD-WINGED KATYDID.

This is the true Katydid. Wing-covers and thorax bright dark green; head, legs and body much paler; hind wings green and transparent. When the insect is at rest the wing-covers curve around the body, so that their edges touch above and beneath; pronotum roughly punctured and somewhat wrinkled; head smooth. The main veins of the wing-covers are very prominent with numerous reticulating branches, giving that organ the appearance of a leaf. Posterior femora short, slender and armed on apical half of lower outer carina with about six small spines. The ovipositor is almost as long as the abdomen, cimeter-shaped, sharp-pointed, and with but slight serrations on the lower edge of apical third. Below the curved anal cerci of the

male is a spine, resembling in appearance the cerci, which curves beneath the projecting sub-anal plate.

Measurements.—Length of body, 30-35 mm.; wing-covers, 33-36 mm., posterior femora, 19-21 mm.

The true Katydids, Figs. 151 and 152, of which several species occur in the United States, differ greatly from other Katydids by having the wings shorter than the wing-covers,

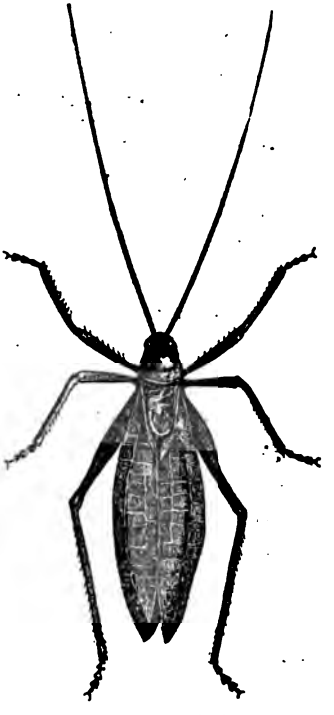


Fig. 151.—*Cyrtophyllus concavus*, male. After Harris.

Fig. 152.—*Cyrtophyllus concavus*, female, *a*, ovipositor, nat. size, *b*, tip of same, enlarged. After Riley.

which latter are very convex, thus giving the insect an inflated appearance. The whole shape of the insect indicates that it can produce a large volume of sound, being almost a sort of sounding board. The structure of the insect also shows that it is decidedly arboreal in habit, the green color well blending with the foliage of the tops of trees where it

dwells. If found in Minnesota it will very likely occur in small colonies; it is most active during August and September.

Prof. Scudder, in describing the loud notes of this insect, writes: "The note, which sounds like *x r*, has a shocking lack of melody; the poets who have sung its praises must have heard it at the distance that lends enchantment. In close proximity the sound is exceedingly rasping and grating, louder and hoarser than I have heard from any other of the *Locustarians* in America or in Europe, and the *Locustarians* are the noisiest of all Orthoptera. Since these creatures are abundant whenever they occur, the noise produced by them, on an evening especially favorable to their song, is most discordant. Usually the notes are two in number, rapidly repeated at short intervals. Perhaps nine out of ten will ordinarily give this number; but occasionally a stubborn insect presists in sounding the triple note (Katy-she-did); and as Katydids appear desirous of defiantly answering their neighbors in the same measure, the proximity of a triple-voiced songster demoralizes a whole neighborhood, and a curious medley results; notes from some individuals may then be heard all the while, scarcely a moment's time intervening between their stridulations, some nearer, others at a greater distance; so that the air is filled by these noisy troubadours with an indescribably confused and grating clatter."

The sub-family *Conocephalinæ* contains two tribes, separated as follows:

a. Fore and middle femora spined beneath...*Conocephalini.*
aa. Fore and middle femora unarmed beneath....*Xiphidiini.*

Only one genus represents the tribe *Conocephalini* in Minnesota.

GENUS *Conocephalus* Thunberg (1815).

Head with the vertex more or less prolonged forward and upward into a cone, with a pointed tooth beneath; face

very oblique; pronotum flat, narrower in front than behind; lateral carina quite sharp, lobes of side curving obliquely backwards in front and well rounded behind. Wing-covers narrow, broader at the base than the apex. Hind wings long and quite narrow. Cerci of male swollen, curved inwards and toothed. Ovipositor very long and straight. The stridulating organ is opaque and of a coarse texture in the left wing-cover, but transparent at the center of the right.

The chief characters by which this genus is recognized are the cone-like process of the vertex, the narrow wings, and the sword-like ovipositor. These insects, not very common in our state, are frequently called "Cone-heads" or "Sword-bearers." Prof. McNeill says about the habits of these insects: "All the species of *Conocephalus* seem to possess more intelligence than is usual in Orthoptera, and they are the most difficult of the order to approach. In escaping they usually slip or fall into the grass instead of jumping or flying; but they seem to fully understand that they are very well protected by their color and form. If approached very cautiously they often remain quite still upon the stem of grass upon which you have surprised them with the usually well founded expectation that you will not be able to distinguish them from the green herbage around. If they think it worth while to make some active movement to escape they will frequently slip around on the other side of the stem and walk down the stem to the ground or off upon another plant. Unlike most Orthoptera they do not use their front legs in holding to the mouth the thing upon which they feed. Instead of biting they seem to wrench or tear away pieces from the stems or leaves."

A number of species occur in Minnesota, but how many is as yet unknown, as but few specimens have been captured, the insects being by no means common.

a. Cone of vertex slender, about 3.5 mm. in length, and with either the margin or lower face black.

b. A black line on each margin of cone extending from the apex half way or more to base; inner, lower carina of posterior femora with four or five minute spines.....*ensiger* Harris.

bb. Cone of vertex entirely black beneath; posterior femora armed on both of the lower carinæ with a number of plainly visible spines.
nebrascensis Bruner.

aa. Cone of vertex rather stout, less than 3 mm. in length, devoid of black markings.....*robustus* Scudder.

Conocephalus ensiger Harris.

THE SWORD-BEARER.

A slender-bodied species, the general color of which is usually grass green, the body and face paler; the posterior tibiæ and tip of ovipositor infuscated. Lateral carinæ of pronotum sometimes with a faint yellow line, more plainly visible in the dried specimens. Tegmina very long and slender. Cone of vertex with a small tooth projecting downward from the front of its base. Ovipositor of excessive length, straight, the apex pointed.

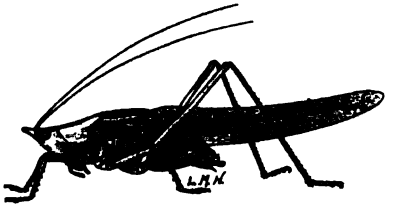


Fig. 153.—*Conocephalus ensiger*, male. Natural size. Original.

Measurements.—Male: Length of body, 26 mm.; of tegmina, 42 mm.; of posterior femora, 21 mm. Female: Length of body, 28 mm.; of tegmina, 47 mm.; of posterior femora, 23 mm.; of cone of vertex, 3.25 mm.; of pronotum, 7.5 mm.; of ovipositor, 31 mm.

This is the best known species of Sword-bearers in Minnesota, and it is by no means very common. It is found among the tall grasses along ditches and swamps. Here in St. Anthony Park it is most frequently observed upon the stems of a coarse grass (*Andropogon*), which grows in dry

and sandy places. The eggs are deposited between the stem and root-leaves of this grass. Other eggs, probably of this insect, are not infrequently found below the scale-like leaves of a common cone-gall on our obtuse-leaved willow. In this case the peculiar shape of the long ovipositor is of great use. Prof. Scudder, who has set the note of the male to music, says of the song: "This insect has but a single song and stridulates only by night, or during cloudy weather. It begins its song as soon as the sky is obscured or the sun is near the horizon. It commences with a note like *b r w*,

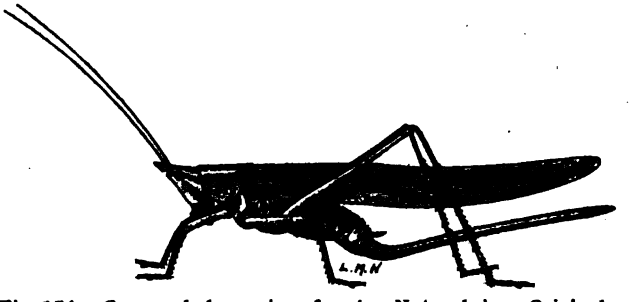


Fig. 154.—*Conocephalus ensiger*, female. Natural size. Original.

then pauses an instant and immediately emits a rapid succession of sounds like *c h w i* at the rate of about five per second, and continues them for an unlimited time. Another writer likens its note to the syllable "*ik-ik-ik*" as if sharpening a saw, enlivening low bushes and particularly the corn patch, as it seems to especially delight in perching near the top of a corn-stalk and there giving forth its rather impulsive song."

The illustrations (Figs. 153 and 154) show both sexes of this peculiar insect.

Conocephalus nebrascencis Bruner.

A shorter winged but heavier bodied insect than *ensiger*. The cone of the vertex projects more strongly upwards, with the apical half more tapering; basal tooth quite prominent. Anal cerci of male stout, with strong internal hooks.

Ovipositor long and slender, lanceolate, a little curved upwards and extending about one-fourth of an inch beyond the closed tegmina. General color bright grass green, rarely a yellowish-brown or tan, with narrow yellowish lines along the lateral carinæ of the pronotum. Posterior tibiæ with all the feet more or less infuscated.

Measurements.—Male: Length of body, 28 mm.; of tegmina, 37 mm.; of pronotum, 8 mm.; of cone of vertex, 3.5 mm.; of posterior femora, 21 mm. Female: Length of body, 33 mm.; of tegmina, 42 mm.; of posterior femora, 23 mm.; of ovipositor, 29 mm.

This insect occurs in the same localities as *ensiger*, and resembles it very closely. It tries to escape by burrowing beneath the dead grass.

Conocephalus robustus Scudder.

A much larger insect, with broader tegmina. Cone of the vertex like that of *ensiger*, but with apex more obtuse; the frontal basal spine blunt and distinct. Posterior femora armed beneath on both carinæ with a number of weak spines. Wings of male equalling the tegmina in length, in the female a little shorter. Ovipositor shorter than in either of the above species. General color either pea-green or dirty brown, or a mixture of both. The cone rarely with a black spot at apex, its sides often with a narrow yellowish line.

Measurements.—Male: Length of body, 30 mm.; of tegmina, 44 mm.; of hind femora, 23 mm.; of pronotum, 8 mm.; of cone, 2 mm. Female: Length of body, 31 mm.; of tegmina, 48 mm.; of hind femora, 26 mm.; of ovipositor, 26 mm.

These large and very noisy insects are found occasionally during September near the shores of Lake Minnetonka and White Bear Lake. But as they seem to inhabit trees they are not readily captured. Besides their loud notes they produce a buzzing sound like the humming of a bee.

The tribe Xiphidiini contains two genera with numerous species.

a. Larger and stouter species. Ovipositor short, falcate. *Orchelimum.*

aa. Smaller and slenderer species. Ovipositor straight and scarcely curved..... *Xiphidium.*

The insects belonging here are usually called "Meadow Grasshoppers."

GENUS *Orchelimum** Serville (1831).

Size medium, body short and stout; face oblique; vertex with a blunt tubercle at the apex, and meeting a small and similar projection from beneath; antennæ very long, thread-like; first joint very stout and cylindrical; second joint considerably smaller; pronotum flat on top, lateral carina well rounded, lobes of sides almost parallel, then forming more or less of a triangle at the bottom. Wing-cases of the male narrow, broad to about the middle, then suddenly but gradually narrowing; stridulating organ well developed. In the female the wing-cases are of about equal width; cerci with a sharp tooth-like hook inside, directed inward; ovipositor slightly curved, and terminating in a sharp point; anterior pairs of tibiæ with a number of spines.

Many specimens of Meadow Grasshoppers are found in Minnesota, and three at least are common, or fairly so, viz., *vulgare*, *glaberrimum* and *nigripes*. Our species have an ovipositor with a very evident curve, not straight or nearly so, and the face without a median brown stripe.

a. Posterior femora unarmed beneath.

b. Tegmina broader at base; the apical third narrower; body robust.

c. Tegmina and wings sub-equal in length; size medium..... *vulgare.*

cc. Tegmina distinctly shorter than wings; size large..... *glaberrimum.*

*Literally, "I dance in the meadows."

bb. Tegmina of equal width throughout; body slender. *campestre.*

aa. Apical half of posterior femora armed beneath with several small spines.

b. All the tibiæ and tarsi black or dark brown..*nigripes.*

bb. The tibiæ and tarsi green or reddish-brown. *silvaticum.*

Orchelimum vulgare Harris.

COMMON MEADOW GRASSHOPPER.

It is a medium sized, robust insect, with the general color green or light reddish-brown. Face light green or light brown without fuscous marks. The occiput and disk of pronotum with a reddish-brown band, widening on the latter, where it is often, especially in the male, bordered on each side with a darker line. The male (as in most of our species) with two short, black dashes on each wing-cover, the four forming the angles of an assumed square, enclosing the tympanum. The legs usually pale brown, the tarsi dusky. Pronotum long, its posterior lobe but slightly, if at all, upturned above the plane of the anterior, its hind margin rounded. Tegmina reaching to or very slightly beyond the apex of hind femora, and equalling or very little shorter than the wings. Cerci of male rather long, the apex bluntly rounded, a little depressed; the sub-basal tooth somewhat flattened, with the tip sharp and decurved.

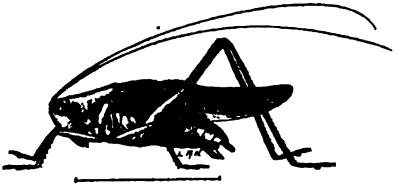


Fig. 155.—*Orchelimum vulgare*, male. Original.

Measurements.—Male: Length of body, 18 mm.; of pronotum, 6 mm.; of tegmina, 21 mm.; of hind femora, 18 mm. Female: Length of body, 19 mm.; of pronotum, 6.2 mm.; of tegmina, 21 mm.; of hind femora, 18.5 mm.; of ovipositor, 7.5 mm.

This is our most abundant meadow grasshopper, and can be found from the end of July until frost. It seems to prefer the higher and dryer meadows and clover and timothy fields. Both sexes are shown in Figs. 155 and 156.

This species is a powerful musician, or rather a noisy one. Prof. Scudder says: "When about to sing on a hot sunny day, the male mounts a stalk of grass about a foot from the ground, where it clings with its four front legs, allowing its hind legs to dangle on either side of the stalk, that they may not interfere with the wing-covers. Beginning with *ts* it changes almost instantly into a trill of *zr*. At first there is a crescendo movement, which reaches its volume in half a second; the trill is then sustained for a period varying from one to twenty seconds, but generally from six to eight seconds, and closes abruptly with *p*. This strain is followed by a series of very short staccato notes sounding like *jip, jip, jip*, repeated at half-second intervals; the staccato notes and trill alternate *ad libitum*. The staccato notes may be continued almost indefinitely, but are very rarely heard more than ten times in direct succession; it ordinarily occurs three or four times when the phrase is repeated."

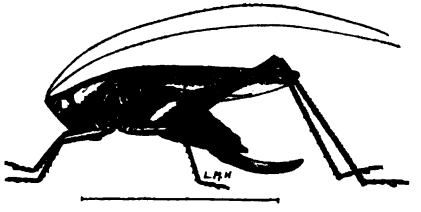


Fig. 166.—*Orchelimum vulgare*, female. Original.

Orchelimum glaberrimum Burmeister.

Very similar to *vulgare*, perhaps only a larger form. The general color is the same, but the brown line on the disk of pronotum is, in the female, more plainly margined with black, while in the male the black dashes at ends of tympanum are larger and more completely enclose that organ. The tegmina of the male exceed the hind femora by about 4 mm., and are exceeded by the wings about the same distance; those of the female are proportionately a little shorter.

Measurements.—Male: Length of body, 22.5 mm.; of pronotum, 6 mm.; of tegmina, 25 mm.; of hind femora, 19 mm. Female: Length of body, 23 mm.; of pronotum, 6.5 mm.; of tegmina, 24 mm; of hind femora, 19 mm.; of ovipositor, 8.5 mm.

A few specimens of this species were found among the tall grass growing near a pond in St. Anthony Park. The insect appears to be not common.

Orchelimum campestre Blatchley.

This insect, of less than medium size, with narrow and almost uniformly wide tegmina, with the posterior femora unarmed beneath, and with a short and narrow ovipositor, has been reported from the south-eastern part of the state, but no specimens have been seen by the writer.

Orchelimum nigripes Scudder.

THE BLACK-LEGGED GRASSHOPPER.

Somewhat smaller than *vulgare;* the body moderately robust. Pronotum short, the posterior lobe, especially in the male, rather strongly upturned. Tegmina a little shorter than the wings, surpassing slightly the hind femora. The shrilling organ of the male is unusually large and prominent with strong cross veins, and behind it the tegmina taper rapidly on both margins; their shape and the size of the tympanum causing the male to appear somewhat peculiar and much more robust than it really is. Hind femora armed on apical half of lower outer carina with from one to four small spines. Cerci of male slender, tapering, the apex a little obtuse; the sub-basal tooth long, slender and a little curved. Ovipositor rather long, broadest in the middle, tapering to a delicate point. The males vary much in size. General color green or reddish-brown, the former prevailing in the male, the latter in the female. Occiput and disk of pronotum with the usual brown markings. Front and sides

of head, and four front femora, reddish-yellow. All the tibiæ and tarsi, together with the apical third of hind femora, black or dark brown.

Measurements.—Male: Length of body, 18 mm.; of pronotum, 5 mm.; of tegmina, 21 mm.; of hind femora, 16 mm. Female: Length of body, 19 mm.; of tegmina, 22 mm.; of hind femora, 17 mm.; of ovipositor, 9 mm.

Not uncommonly found in low places along the Mississippi River, where it seems to prefer to dwell on such plants as the Smartweed.

GENUS *Xiphidium* Serville (1831).

Very closely allied to the genus *Orchelimum*, from which it can hardly be separated. The species, however, are much smaller and more graceful, and the ovipositor is straight instead of curved. Wings as long, longer or shorter than the abdomen. Wing-length in this genus, and in *Orchelimum*, is a character not to be relied upon as a specific or even a varietal difference.

These light-green grasshoppers are found in large numbers in our meadows and moist pastures. Here they give concerts from the middle of summer till the autumn. Insects belonging to this genus possess no conical projections upon their heads.

We have in Minnesota several species of these insects, and no doubt still others will be found.

A. Ovipositor shorter than the body.
  b. Ovipositor straight.
    c. Wings a little longer than the wing-covers; the latter always fully developed.....*fasciatum*.
    cc. Wings shorter than the wing-covers; the latter variable in length.....*brevipenne*.
  bb. Ovipositor a little curved; tegmina constant in length, covering about two-thirds of the abdomen in the male; shorter in the female.....*nemorale*.

AA. Ovipositor equal to or longer than the body.

b. Length of posterior femora almost equal to that of ovipositor.
  c. Body rather stout; the tegmina always covering more than half the abdomen.
    d. Abdomen with the dorsal surface light brown, the sides green, or greenish-yellow. *ensiferum.*
    dd. Abdomen with the dorsal surface a fuscous brown, the sides shining-black. *nigropleurum.*
  cc. Body very slender; the tegmina exceedingly short, pad-like, covering only one-third of the abdomen ..... *modestum.*
bb. Posterior femora much shorter than the ovipositor; the latter of excessive length.
  c. The common form with the tegmina very short, less than half the length of the abdomen; the sides of the body green..... *strictum.*
  cc. The common form with the tegmina covering three-fourths or more of abdomen; sides of body dull reddish-brown..... *antennatum.*

Xiphidium fasciatum DeGeer.

THE SLENDER MEADOW GRASSHOPPER.

Pale green, with a broad reddish-brown, longitudinal band on its thorax, extending to the top of the head, where it becomes much narrower; face entirely green; abdomen above reddish, green beneath. Wing-covers and wings extending much beyond the body, reaching the tip of the ovipositor in the female. Hind wings somewhat longer than the wing-covers.

Measurements.—Length of body, 13.5 mm.; wing-covers, 17 mm.; hind femora, 11 mm.; ovipositor, 8 mm.

This is one of the most slender bodied species, and the only one whose wings are never shorter than the

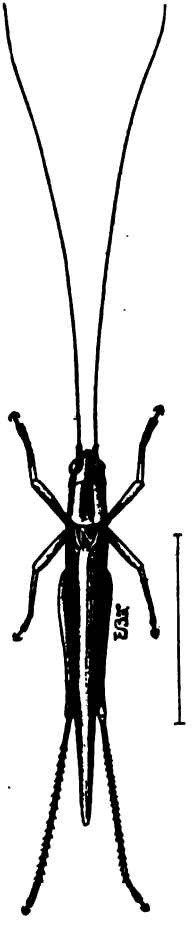


Fig. 157.—*Xiphidium fasciatum*, male. Original.

body. It is found abuntantly everywhere in timothy and clover fields, and especially in low pastures. It reaches maturity very early, and about July 10 the first notes of the males can be heard; they are a kind of *zr-r-r-r* long drawn out.

Both sexes are shown in Figs. 157 and 158.

Xiphidium brevipenne Scudder.

Smaller and somewhat stouter than *fasciatum*. Color light green or pale brown, with the band on the thorax and head the same as in *fasciatum*, wings almost as long as the body, and not extending beyond it. Antennæ about three times as long as the body. Posterior femora rather short, and stout, unarmed beneath,

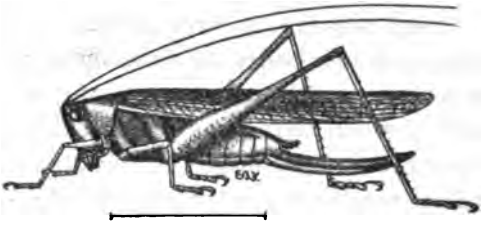


Fig. 158.—*Xiphidium fasciatum*, female. Original.

or rarely with one to four minute spines. Cerci of male swollen, the apex strongly compressed and obtuse, armed below the middle with a rather flat, sharp-pointed tooth. Ovipositor reddish-brown throughout.

Measurements.—Length of body, 9-12 mm.; wing-covers, 6-8 mm.; posterior femora, 11-12 mm.; ovipositor, 9-12 mm.

This common species occurs in the same localities as *fasciatum*, but reaches maturity about a fortnight later.

Xiphidium nemorale Scudder.

Greenish-brown; wing-covers greenish with the front margin blackish, nearly as long as the abdomen in the male, somewhat shorter in the female; top of head and pronotum with a broad, very faint, reddish, longitudinal stripe margined with a whitish line on each side; legs greenish with many red dots; wing-covers with prominent cross-veins; ovipositor as long as the abdomen, slightly curved upwards apically.

Measurements.—Male: Length of body, 14 mm.; wing-covers, 8 mm.; hind femora, 12 mm. Female: Length of body, 15 mm.; wing-covers, 5.5 mm.; hind femora, 13 mm.; ovipositor, 9 mm.

This rather common species prefers the borders of our forests, and seems to be at home amongst the low bushes found in such localities.

Xiphidium ensiferum Scudder.

Very similar to *brevipenne;* general color more of a green, the face, sides of pronotum and abdomen, and the four anterior femora being of that hue. Tegmina and wings light reddish-brown, as are the tibiæ and ovipositor, the latter becoming a deeper brown towards the apex. Cerci of male rather stout, with the apical half curved slightly outward and depressed. Ovipositor slender, straight.

Measurements.—Male: Length of body, 13.5 mm.; of tegmina, 9 mm.; of hind femora, 13 mm.; of pronotum, 3.5 mm. Female: Length of body, 14.5 mm.; of tegmina, 8.5 mm.; of hind femora, 14 mm.; of ovipositor, 15 mm.

This peculiar grasshopper is common in many parts of the state. It has the peculiar habit of selecting the common cone-shaped willow-gall as the place in which to deposit the eggs. Prof. Wheeler published an excellent account of the

oviposition of this species. He writes: "On September 8th I observed a female in the act of oviposition. She was perched with her head turned toward the apex of the gall. Slowly and sedately she thrust her sword-shaped ovipositor down between the leaves, and, after depositing an egg, as slowly withdrew the organ in order to recommence the same operation, after taking a few steps to one side of where she had been at work. She soon observed me and slipped away without completing her task. The number of eggs found in a gall varies considerably. Sometimes but two or three will be found, more frequently from fifty to a hundred. In one such gall I counted one hundred and seventy." The egg is cream colored, very thin, elongate-oval in outline, and measures 4x1 mm. The young emerge about the middle of May and reach maturity toward the middle of August. Long-winged forms are found occasionally.

Xiphidium nigropleurum Bruner.

THE BLACK-SIDED GRASSHOPPER.

A medium sized, rather robust species, easily distinguished from all others of the genus by its peculiar coloration. Two forms occur, one having the pronotum, tegmina and legs bright grass-green, the other with these parts brownish-yellow, the green entirely absent. Both forms have the stripe on the occiput and the sides of the abdomen shining black; the former narrowing in front to the width of the tubercle, and bordered on each side with yellowish-white. In the green forms the usual brown stripe on the disk of the pronotum is but faintly defined; in the other it is very evident. The tegmina are usually abbreviated, reaching only four-fifths of the length of the abdomen, but an occasional specimen is to be found in which the wings are fully developed and then reach to the extremity of the ovipositor of the female. Ovipositor straight, quite broad and heavy. Male cerci of medium length, rather stout, tapering gently toward the apex, and with a strong sub-basal tooth.

Measurements.—Male: Length of body, 14 mm.; of tegmina, 9 mm.; of hind femora, 13.5 mm.; of pronotum, 3.5 mm. Female: Length of body, 15 mm.; of tegmina, 8.5 mm.; of hind femora, 14 mm.; of ovipositor, 16 mm.

This species is found, rarely, in low and swamp places.

Xiphidium modestum Bruner.

This small species, of a dull reddish-brown color, has been reported from the southern part of Minnesota, but no specimens have been seen by the writer. It is said to be common west of the Mississippi River.

Xiphidium strictum Scudder.

Body rather slender, of more than the average length. Two forms, constant in color, but dimorphic as far as the length of wings is concerned, are found. Sides of head and body together with all the femora green. The usual reddish-brown stripes on occiput and pronotum narrowly edged with whitish. Tegmina reddish-brown; in the females exceedingly short and pad-like, or well developed and reaching almost to knees; when the former, a little longer than the wings; when the latter, 5 mm. shorter than the wings. In the short-winged males the tegmina are somewhat less than half the length of the abdomen. There is a reddish-brown band on the dorsal surface of abdomen, darker where it meets the green on sides. Ovipositor pale red, straight, one and a half times the length of the posterior femora. Cerci of male long, the apical half acuminate, curved slightly inward near the tip.

Measurements.—Male: Length of body, 14 mm.; of tegmina, 5.5 mm.; of pronotum, 3.5 mm.; of hind femora, 13.5 mm. Female: Length of body, 17 mm.; of tegmina, short-winged form, 3.5 mm.; long-winged form, 16 mm.; of hind femora, 15.5 mm.; of ovipositor, 23 mm.

Rather common in the south-western part of the state, in the dry prairies.

Xiphidium attenuatum Scudder.

THE LANCE-TAILED GRASSHOPPER.

A medium sized grasshopper, with the sides of the head and body dull reddish-brown. Vertex, disk of pronotum, and tegmina greenish-brown in life, the former with the

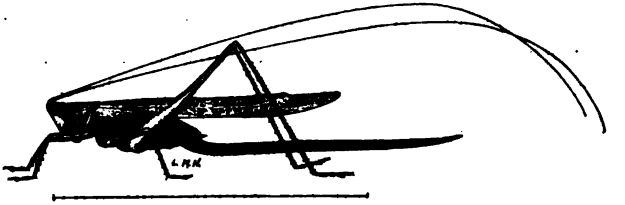


Fig. 159.—*Xiphidium attenuatum*, female. Original.

usual dark-brown median stripe. Femora greenish-brown, very rarely bright green, the tibiæ and tarsi darker. Tegmina and wings either abbreviated or fully developed—when the former, covering about three-fourths of the abdomen, when the latter considerably surpassing its tip in both sexes. Antennæ with the basal third reddish, the remainder fuscous, longer than in any other member of the genus belonging to our fauna. Ovipositor also longer than in any other; slender and nearly straight, the apex very acuminate; cerci of male long, with the apical third gently tapering, the basal tooth minute, slender.

Measurements.—Male: Length of body, 14 mm.; of pronotum, 3 mm.; of tegmina, short form, 10 mm.; of hind femora, 14.5 mm.; of antennæ, 73 mm. Female: Length of body, 16 mm.; of tegmina, 9.5 mm.; of hind femora, 15 mm.; of ovipostor, 26-30 mm.

A few specimens of the short-winged form have been taken in Minnesota (Fig. 159 shows a long-winged female). Prof. Blatchley says: "The males of *attenuatum* are, as far as my experience goes, the most active leapers among the winged *Locustidæ*, jumping a half dozen or more times without pause when flushed, and in the net leaping so rapidly from side to side as to prevent capture with the fingers.

The females are evidently handicapped in their leaping powers by the excessive length of the ovipositor, and so more often endeavor to escape by burrowing beneath the dense masses of fallen grass and reed-stems which are always found in their accustomed haunts."

He also finds that the length of the ovipositor among the different species of *Xiphidium* is not at all dependent upon the age of the insect. In *attenuatum* it is almost as long after the third, and fully as long after the fourth molt as it is in the imago.

The eggs of *attenuatum*, as the length of the ovipositor indicates, are laid between the stems and leaves of tall grasses.

The sub-family *Decticinæ* contains a large number of genera, of which only two occur in Minnesota, and very sparingly at that.

a. Prosternum armed with two erect spines. Large but not bulky insects ..... *Atlanticus.*

aa. Prosternum unarmed. Large and very bulky insects. *Anabrus.*

GENUS *Atlanticus* Scudder.

Head rounded; face broad, but slightly oblique; vertex compressed, with a blunt, decurved projection between the antennæ, which is slightly excavated on the sides; pronotum flattened on top with the lateral carinæ sharp and abruptly bent down at the sides. The pronotum is narrower in front than behind, and slightly pinched before the middle; it also extends backwards over the first abdominal segment. Wing-covers of the female rudimentary and hidden under the pronotum; those of the male about half as long as the body; ovipositor stout at base, straight, flattened, and pointed obliquely upwards; as long as the body. The shrilling organ, which is covered by the pronotum, is circular, and rather large for the size of the tegmina.

Atlanticus pachymerus Burmeister.

SHIELD-BACKED GRASSHOPPER.

Grayish-brown, with the wing-covers of the male marked with black. The abdomen and femora are sprinkled with minute blackish dots. The extreme lateral edge of the pronotum with a yellowish border, preceded by a black streak at the posterior edge.

Measurements.—Male: Length of body, 20 mm.; of pronotum, 10 mm.; of hind femora, 16 mm. Female: Length of body, 22 mm.; of pronotum, 9 mm.; of hind femora, 18 mm.; of ovipositor, 17 mm.

Only a few of these wingless and dull-colored grasshoppers were found. The insects are very striking, owing to the large size of the pronotum, which is so enlarged as to extend back over the two other thoracic segments. The ovipositor of the female is also greatly developed and almost straight.

The fully-grown insect (Fig. 160, male) is found early in July; it seems to prefer the dry hill-sides. The young appear very early in the season, and are much more active during this period than in their mature state, when they crawl rather than leap. In captivity they feed as readily upon animal as upon vegetable food, and in the natural state probably feed upon the dead bodies of such small animals as they can find. The adults are far less numerous than the young, being probably killed by ground-feeding birds, as they do not hide by day as do the various kinds of *Ceuthophili*. The adults are sometimes found resting on the leaves and stems of low shrubs and weeds, but seldom climb over two or three feet from the ground. Their song resembles that of *Orchelimum vulgare*. It is a

Fig. 160.—*Atlanticus pachymerus*, male. Original.

continuous *z-e-e-e*, with an occasional short *ik*, caused by the insect getting its wing-covers ready for action after a period of silence.

A second species (*A. dorsalis* Burm.) may possibly be found in our state. The two species can be separated by the characters given in the following table:

a. Front margin of pronotum much shallower, but little more than half as wide as hind margin, the latter broadly rounded.....*pachymerus.*

aa. Front margin of pronotum but little narrowed, almost three-fourths the width of the hind margin, the latter almost square.....*dorsalis.*

GENUS *Anabrus** Haldeman.

Bulky and large insects. Pronotum extending over the basal portion of the abdomen concealing the rudimentary, squamæform elytra; without distinct lateral carinæ, and the median carina wanting or visible only on the posterior portion; dorsum of pronotum smooth. Prosternum unarmed. Anterior tibiæ with six to eight spines in front, in two rows; tarsi broad, soles concave, the third articulation cordate. Styles of sub-genital plate of males articulated. Ovipositor nearly straight, sword-shaped, two-thirds the length of the body.

The genus resembles *Atlanticus* in the shield-like pronotum and large size of the ovipositor, but differs in having the prosternum unarmed, while in the former genus there are two spines between the base of the front legs.

Anabrus purpurascens Uhler.

This dark purplish-brown insect, mottled with yellow, occurs in the Red River Valley, where at least one specimen was found near Argyle Further west, where the insects belonging to this and other species are very much more com-

*ἄβρος, with the negative prefix ἀν, in allusion to the unprepossessing appearance of the insect.

mon, they are called "Western Crickets." They sometimes become very destructive to crops. The insect deposits in August and early September from 50 to 75 eggs, which have a cylindrical, long-oval shape, and have their pearly white surface minutely pitted; they hatch late in spring.

Fig. 162.—*Anabrus purpurascens*, female. Original.

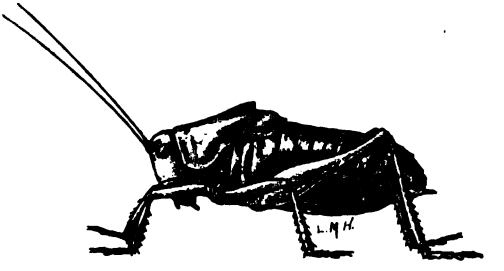


Fig. 161.—*Anabrus purpurascens*, male. Original.

Both sexes are illustrated (Figs. 161 and 162) in natural size.

The sub-family *Gryllacrinæ* is not represented in the fauna of Minnesota, and the sub-family *Stenopelmatinæ* by only one tribe, the *Rhaphidophorini*, which contains a number of genera belonging to the group of *Ceuthophili*.

a. Palpi long. Hind tibiæ usually considerably longer than the hind femora. Third hind tarsal joint only half or less than half as long as the second.....*Ceuthophilus*.

aa. Palpi short. Hind tibiæ shorter, or at most but little longer than the hind femora. Third hind tarsal joint hardly shorter than the second.....*Udeopsylla*.

GENUS *Ceuthophilus* Scudder (1862).

Wingless, medium or large, head large, oval, bent downwards and backwards between the front legs; vertex not tuberculate; last joint of palpi longer than the third, and

grooved beneath at the apex; antennæ very long, usually two or more times as long as the body; pronotum not extending over the meta- and mesothorax as in *Atlanticus*, and well rounded on top; prosternum unarmed; abdomen arched; legs long, slender, with a few spines; hind femora swollen at the base, channeled beneath, and more or less spined; hind tibiæ with more than four pairs of spurs, first tarsal joint almost as long as the rest together; ovipositor straight, more or less swollen at the base.

All members of this and allied genera live in dark and moist places, under rotten logs, stones, mole-hills, in cavities, or in cellars. A related insect, the "Cave Cricket," is found in our large caves; it is colorless and blind, but possesses long legs and antennæ. Another species lives in Florida in the burrows of a turtle, the "Gopher." All are wingless grasshoppers which, on account of their resemblance to genuine crickets, are called "Cricket-like Grasshoppers" or "Stone Crickets." Their color, which is a pale brown, dirty white, or quite dark and almost black, harmonizes well with their surroundings, and the mottled appearance of some adds to their protection.

The males of these peculiar beings are readily separated by the size, number and relative positions of the spines on the under side of the hind femora, as well as by the degree of curvature of the corresponding tibiæ. The females, having neither the spined posterior femora nor the curved tibiæ, are less readily distinguished. As the two sexes are colored alike, and are usually found together in some hiding place, there will be little difficulty in placing the female after determining the male by the characters given.

These insects are almost omnivorous in their choice of food, and like most *Locustidæ* feed upon meat whenever they can obtain it.

Ceuthophilus maculatus Say.

SPOTTED WINGLESS GRASSHOPPER.

Glabrous, mottled with luteous and blackish, the darker markings predominating; on the pronotum a luteous, medio-dorsal stripe, also traces of such a stripe along the dorsum of the meta- and mesothorax; the hind femora are strongly infuscated outside and inside; the anterior pairs of femora infuscated at the apex and all the tibiæ at the base; posterior tibiæ infuscated along the upper side; fore femora a little more than a fourth longer than the pronotum and much less than half as long as the hind femora; hind femora as long as the body, three and a half times as long as broad, moderately stout at base, and with no raised points on the upper or inner surface; outer carina with about thirteen unequal coarse spines in the male, and minute distant inconspicuous spinules in the female; inner carina with similar but uniform spines, none so long as on the outer carina (male) or with a few minute spinules on the apical half (female), the intervening sulcus not very broad. Hind tibiæ feebly undulate in the basal half in the male. Ovipositor nearly two-thirds as long as the hind femora.

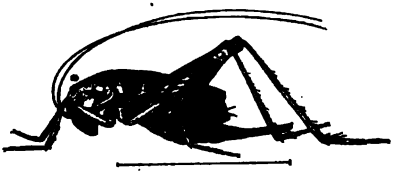


Fig. 163.—*Ceuthophilus maculatus*. female. Original.

Measurements.—Male: Length of body, 14 mm.; pronotum, 5 mm.; fore femora, 6.6 mm.; hind femora, 15.25 mm.; hind tibiæ, 16.25 mm. Female slightly larger; ovipositor, 10 mm.

This is our most abundant species, quite common under decaying wood, loose bark, and under stones. It is illustrated in Fig. 163.

Ceuthophilus Blatchleyi Scudder.

Dull yellowish or reddish, heavily mottled with dark fuscous, leaving a narrow medio-dorsal streak on pronotum;

the flecking is made up of small more or less confluent dots, which assume a certain longitudinal regularity only on the abdomen; legs varying from luteous to testaceous, more or less infuscated. Fore femora no stouter than the hind femora, much less than half as long as the fore femora, fully a third (male) or scarcely a fourth (female) as long again as the pronotum, the inner carina with 2-3 spines, the sub-apical long. Middle femora armed on the front carina much as in the fore legs, the hind carina with a long genicular spine sometimes accompanied by 1-3 other spines, often minute. Hind femora nearly two and a half times as long as the fore femora, longer than the body in both sexes, slender and tapering, nearly the apical third sub-equal, three and a half times as long as broad in the male and fully three and three-quarters in the female, the upper portion of the apical half of the inner surface and to a less degree the upper surface near it with numerous raised points, the outer carina with wider intervals between the larger spines and the spines less stout (male), or with 2-3 scarcely noticeable spinules near the apex (female), the inner carina with about 12-14 serrulations unequally placed, slight, less numerous and distinctly slighter in the female than in the male, the intervening sulcus only moderately broad. Hind tibiæ with a hardly noticeable arcuation or sinuation in the male, hardly (male) or much (female) longer than the femora, slender, armed beneath with two median sub-apical spines besides the apical pair. Hind tarsi about two-fifths as long as the tibiæ, the first joint longer than the other joints together, the second much more than twice as long as the third and with it longer than the fourth. Cerci stout at base, beyond slender, about as long as the femoral breadth. Ovipositor straight, almost two-thirds as long as the hind femora, very little enlarged at base, tapering almost throughout but very gently, the tip upturned a little and finely acuminate.

Length of body, 13-13.5 mm.; pronotum, 4.5-4.7 mm.; fore femora, male, 6.4 mm., female, 5.5 mm.; hind femora,

male, 15.75 mm., female, 13.5 mm.; hind tibiæ, male and female, 16.25 mm.; ovipositor, 8.5 mm.

Ceuthophilus lapidicolus Burmeister.

This species is closely allied to *maculatus*, but differs

Fig. 164.—*Ceuthophilus lapidicolus*, female. Original.

from it in the style of mottling of the upper surface, and in that the males do not have the posterior tibiæ waved. A female is shown in Fig 164.

Ceuthophilus gracilipes Hald.

Ground color of body varying from luteous to dark castaneous, very heavily marked with blackish fuscous so that the latter is often the prevailing tint; the darker colors prevail always on the hinder half of all the segments but the pronotum; the anterior edge of the dark posterior markings of each segment, especially in the front portion of the body, is exceedingly irregular and broken, and the lightest parts are more or less irregularly clouded with fuscous; the femora are usually of the prevailing tint of the body. Antennæ moderately coarse at the base, tapering with great regularity, 3-4 times the length of the body. Legs very long and slender. Fore femora no stouter than the middle femora, more than half as long again as the pronotum, especially in the male, distinctly less than half as long again as the fore femora, the inner carina usually with 2-3 spines, often rather long in old individuals. Middle femora with 3-4 spines on either carina, the hind carina with a not very long genicular spine. Hind femora as long as or longer than the body, considerably more than twice the

length of the fore femora, very stout at base, but gradually diminishing in stoutness so that the distal third is slender and sub-equal and the whole less than three and a half times longer than broad, the surface mostly glabrous, but on the darker portions above beset not very sparsely with feeble raised points, the outer carina with about thirteen distant unequal rather coarse spines, the longest shorter than the tibial spurs (male) or almost unarmed (female), the inner carina much less elevated than the outer, with equal abortive denticulations numerous in the male, infrequent and equidistant in the female, the intervening sulcus moderately broad. Hind tibiæ rather slender, straight, nearly a sixth longer than the femora. Hind tarsi much less than half as long as the tibiæ, the first joint not so long as the rest together, the second nearly three times as long as the third and with it fully as long as the fourth. Cerci stout at base, tapering throughout. Ovipositor with the basal third rather stout, beyond equal and rather slender, nearly three-fourths the length of the hind femora.

Length of body: Male, 19 mm., female, 23 mm.; pronotum, male, 5.75 mm., female, 6.75 mm.; fore femora, male, 10 mm., female, 10.6 mm.; hind femora, male, 21.5 mm., female, 22 mm.; hind tibiæ, male, 24.75 mm., female, 25 mm.; ovipositor, 15.5 mm.

GENUS *Udeopsylla* Scudder.

Body heavier and stouter than in *Ceuthophilus*, with a larger head. First joint of antennæ larger and stouter than the rest, as broad as long, compressed anteriorly; third joint twice as long as second; remainder unequal; eyes small; sub-pyriform, docked on the antennal border, globose; maxillary palpi rather long; first and second joints equal and small; third, more than equal to the preceding together; fourth, little more than half as long as third; fifth, a little longer than third, somewhat curved, split along the whole underside; as in *Ceuthophilus* the pro-, meso- and meta-

nota nearly conceal the epimera of the thoracic segments; coxæ differing but slightly from *Ceuthophilus;* hind femora very heavy, thick, and especially broad; in the males the hind femora are spined beneath; the fore and middle femora are shorter and heavier than in *Ceuthophilus;* tarsi, with the first and fourth joints equal and longest; second and third equal and small, the second overlapping the third above; the ovipositor is rather short, thick at base, slender at apical half.

Two species are found in Minnesota.

Body piceous, occasionally with faint rufous spots. *nigra.*

Body varying in color from dark testaceous to mahogany brown.....*robusta*

Udeopsylla nigra Scudder.

Shining black, with a faintly indicated, narrow, reddish dorsal line, a reddish tinge on the front of the face, the basal half of the inner surface of hind femora and the terminal half of the ovipositor, reddish. The hind femora of the male have upon either edge of the under surface, but especially on the inner, short but heavy spines, not crowded; the third tibiæ are furnished on either edge of the upper surface with four or five opposite, long, and slender spines, between each two of which are placed three or four suppressed spines; there is a single row of short spines upon the under surface, which become double towards the tip; the inner valves of the ovipositor have five teeth, growing longer and more curved towards the tip, where they are very long and slender.

Measurements.—Length of body, 20-23 mm.; of hind femora, female, 14 mm., male, 18 mm.; of ovipositor, 8.25 mm.; of antennæ, 25 mm.

A specimen was found on June 28 in an old cellar in Hamline; others in the Red River Valley under some rubbish lodged against an old log.

Udeopsylla robusta Hald.

"Uniform dark fuscous, dorsum and upper surface of the femora sparsely scabrous; feet rather short; posterior femora of female very robust, rather suddenly contracted inferiorly at the extremity; inferior margin with a row of robust spines upon the inside; tarsi tetramerous. Length thirteen lines."

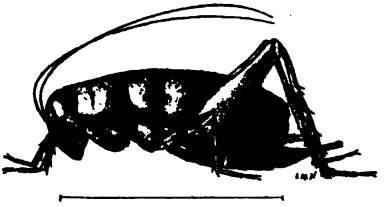


Fig. 165.—*Udeopsylla robusta*, female. Original.

This insect is by no means common, but a few specimens were taken near a gopher hole in a small prairie, but near a grove of trees. It is shown in Fig. 165.

Among the curious insects which are from time to time introduced in various ways from other countries, one species, illustrated in Fig. 166, has succeeded in finding a new home in the conservatory of the State University at Minneapolis.

Fig. 166.—*Diestrammena marmorata*, male. Original.

Prof. O. W. Oestlund has kindly furnished the following note in regard to it: "All the facts that I can obtain regarding this insect (Fig. 166) are that they have been now in the conservatory for the last three years, and that they multiply freely. They were at first noticed in connection with a shipment of plants from Florida, consisting mostly of the Japanese Umbrella-plant. There was also a great deal of straw used in packing, which no doubt aided in the transportation of the insect. At the same time there also appeared a cater-

pillar very destructive to ferns, but which was exterminated the first year." The latter was a Florida species.

Dr. S. H. Scudder has kindly determined the former insect, and he pronounces it *Diestrammena marmorata* (De Haan) of Japan. This instance shows how easy it is for insects to reach new quarters, and, if these should suit their requirements, to find a new home.

FAMILY VII. *Gryllidæ*.

CRICKETS, ETC.

The members of this family of jumping orthoptera resemble the members of the previous family, *Locustidæ*, in possessing long, slender and delicately tapering antennæ; they differ from them in the form of their wing-covers, the number of joints in the tarsi, and in the form of the ovipositor. The tegmina in the *Gryllidæ* are horizontal, with the outer portion bent abruptly downwards; the tarsi are three-jointed, with the exception of *Œcanthus*, in which the hind tarsi are four-jointed; and the ovipositor is usually long and spear-shaped. The sexes differ greatly in structure, the female having a long ovipositor and the venation of the tegmina simple, while the male has the veins upon the horizontal part of the tegmina so modified as to admit of their being used as a musical organ.

Prof. Scudder uses the following table to distinguish the sub-families:

SUB-FAMILIES OF GRYLLIDÆ.

A. Tarsi compressed, the second joint minute, compressed.

b. Fore legs fossorial; female without ovipositor; tympanum of male tegmina (when present) without speculum.....*Gryllotalpinæ*.

bb. Fore legs gressorial; female with ovipositor, though it is sometimes rudimentary; tympanum

of male tegmina (when present) furnished with a speculum.

c. Hind tibiæ biseriately serratulate but not spined, or, if spined (*Myrmecophila*), then the body is sub-spherical and the hind femora exceptionally gibbous.....*Myrmecophilinæ*.

cc. Hind tibiæ biseriately spined, the body always sub-elongate, with relatively slender hind femora.

d. Hind tibiæ rather short, armed with stout spines, not serrulate between them.

Gryllinæ.

dd. Hind tibiæ slender, armed with delicate spines, and serrulate between them.

Œcanthinæ.

AA. Second joint distinct, depressed, cordiform.

b. Hind tibiæ biseriately spinose, not serrate, the apical spurs, two in number on the inner side.

Trigonidiinæ.

bb. Hind tibiæ biseriately spinose and also serrate, the apical spurs, three in number, on both sides.

Eneopterinæ.

The sub-family *Gryllotalpinæ* contains two tribes.

A. Head furnished with two large ocelli; fore tibiæ dilated, markedly digitate; hind femora scarcely saltatorial; tarsi three-jointed.....*Gryllotalpini*.

AA. Head furnished with three small ocelli; fore tibiæ scarcely dilated, three to four spined apically; hind femora strongly saltatorial; tarsi uniarticulate or aborted.....*Tridactylini*.

GENUS *Gryllotalpa Latreille*.

Head oval; thorax convex, sub-elliptical, sides rounded; body rounded and about twice as long as the thorax; an-

terior legs very stout and strong, broad and flattened, with two spines at the tip and a movable claw-like organ outside, with two spines; middle legs short and slender; hind legs longer. Wing-covers about half as long as the abdomen; wings half as long or longer than the abdomen.

Two species of these curious insects are found in Minnesota, but both are rather uncommon, at least as far as known.

Gryllotalpa borealis Burmeister.

THE NORTHERN MOLE-CRICKET.

Cinnamon brown, covered with short, fine hairs of the same color. The wing-covers are less than one-half as long as the abdomen, and the wings extend a little beyond the wing-covers. Length, about 30 mm.

Fig. 167, *b*, shows the enlarged claws, from the side.

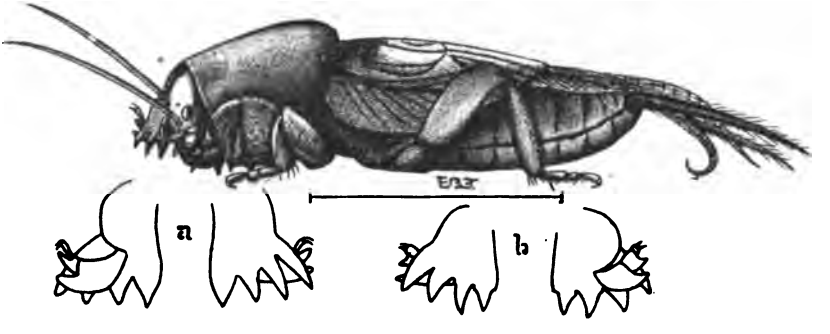


Fig. 167.—*Gryllotalpa columbia: a*, side view of anterior claw; *b*, the same of *G. borealis*. Original.

Gryllotalpa Columbia Scudder.

THE LONG-WINGED MOLE-CRICKET.

Differs but slightly from *borealis*, but has the upper wings somewhat longer, and the hind wings extending beyond the tip of the abdomen.

This curious insect is shown in Fig. 167. The anterior claws, Fig. 167, *a*, differ but little from those of *G. borealis*.

These fossorial crickets, like the members of the following genus, burrow in the ground, but especially the former are preeminetly burrowers. Like the true mole they are well equipped for such a life. Unity of habits will produce similar modifications in the organs specially needed, and the front tibiæ of the mole-crickets are very similar to the broadened hand-shaped front feet of the mole, or of the pocket-gopher, because they are used for the same purpose. Mole-crickets live in rather damp places, near lakes, ponds or rivers, where they form long channels with raised ridges, which resemble a miniature mole-hill. Some of their burrows are from six to eight inches below the surface, and in making them the roots of plants above are greatly injured. Mole-crickets, though they feed upon tender roots of plants, are by no means strictly vegetarians, but devour greedily any insect they are able to catch. In fact most of the members of Crickets and Long-horned Grasshopers are cannibals whenever an opportunity should offer, and some eat more animal than vegetable matter. In Europe the mole-cricket becomes sometimes a very serious pest, especially among young plants of trees in forest nurseries. In the West Indies, and in Java, other species are very destructive to the sugar-cane.

Mole-crickets, like true moles, are by no means socia beings, and except at the love season only one adult insect is found in each burrow. The mother deposits from 200 to 300 eggs in a round cavity deeper in the ground. Wherever mole-crickets occur they are not very difficult to capture, as they can be located in their burrows by their songs. Captive specimens, if placed on the ground, will at once begin to dig; if put on a piece of paper, or on a handkerchief, they invariably go through all the motions of digging. Both species of mole-crickets are sometimes attracted by lights.

GENUS *Tridactylus* Oliver.

Body glossy. Head and pronotum convex; eyes oval; antennæ short; wing-covers not reaching the end of the body; wings longer or shorter, folded lengthwise like a fan. Anterior tibiæ broad and flat, armed at the end with three spurs; all the tarsi very slender; posterior femora long and broad, with a rounded shallow depression at the end. Body narrower than the thorax.

Tridactylus terminalis Scudder.

Head and thorax pitchy black, glossy, sometimes with reddish-brown spots. The hind femora are black with two white spots or fasciæ. The wings reach to the tip of the abdomen, or extend a little beyond, in both sexes. Length about 7 mm.

Tridactylus apicalis Say.

Fig 168—*Tridactylus apicalis*. Original.

Body deep black, head and thorax with some white markings, tegmina with outer edge and a spot behind the middle white. Hind femora whitish, with three faint, dark cross bars. Wings of male extend 3 mm. beyond tip of abdomen. Length 8 or 9 mm.

This is the largest species occuring in the U. S. Only a single specimen was captured as late as Oct. 14 on the bank of a little stream near Ft. Snelling. It is illustrated in fig. 168.

Tridactylus minutus Scudder.

This insect has not been found as yet in Minnesota, but very likely occurs here as well as further south.

The generic name *Tridactylus* is based upon the peculiar structure of the anterior tibiæ, which are much dilated and armed at the end with three strong and slightly curved spurs. The insects forming this genus resemble mole-crickets in form and general appearance, but are very much

smaller and brighter colored. Like the mole crickets they burrow, but are not so helpless away from their tunnels, as they can jump as well as the true crickets. It is not easy to capture them, as their power of leaping is so marvelous that they seem to disappear most mysteriously, the eye not being able to follow them in the air.

The sub-family *Myrmecophilinæ* is represented by a single genus in Minnesota.

GENUS *Myrmecophila* Latreille.

Besides the characters already given in the table this genus is distinguished by the absence of compound eyes; ocelli present; hind femora ovate; hind tibiæ dilated, with only three or four apical spurs.

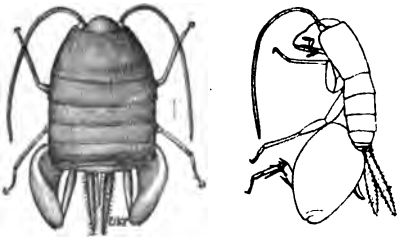


Fig. 169.—*Myrmecophila nebrascensis*. Original.

No doubt a number of species occur in our state. The insects are found only in the nests of ants, and consequently are not readily observed. Yet a number have been seen when searching for other insects in such nests. When moving about quietly the insects resemble very closely young cockroaches, also found in similar surroundings, but as soon as disturbed they prove the usefulness of the tremendous muscles located in their swollen hind femora. Males are exceedingly rare, in fact unknown in the European species. *Myrmecophila nebrascensis* Brun., is shown in fig. 169.

The sub-family *Gryllinæ* contains two genera in Minnesota.

A. Hind tibiæ furnished with long, mobile, pilose spines; first joint of hind tarsi unarmed above or with one row of serrations..... .....*Nemobius.*

AA. Hind tibiæ armed with strong fixed spines; first joint of hind tarsi sulcate, with two rows of serrations. *Gryllus.*

Most crickets, if not having a home in cracks, in walls, or below stones, make burrows in the ground in which they live. The eggs are laid in the autumn, and usually in the ground, after which the greater number of the old crickets die; a few survive, however. The eggs hatch quite early in the spring. The insects are omnivorous, feeding upon all kinds of decaying matter as well as upon living plants, hence must be classed among the injurious insects; they eat also many insects, and freshly dropped cow dung seems to be especially attractive to them. Those crickets that make burrows in the ground can become quite injurious by exposing the roots of plants to the drying influence of the air.

GENUS *Nemobius* Serville.

Small sized species. Head and thorax with comparatively long hairs; first and second joints of maxillary palpi minute, third and fifth joints of about equal length, fourth joint smaller. The venation of the wing-covers of the female differs from *Gryllus*, the veins running longitudinally, while in *Gryllus* they run obliquely from both sides, thus forming lozenge-shaped spaces between. Hind tibiæ with long spines of unequal length. Ovipositor straight, longer or shorter than the abdomen.

Nemobius fasciatus DeGeer.

SMALL STRIPED GROUND-CRICKET.

Dusky brown to almost piceous, with head and thorax hairy; the wing-covers and legs sometimes paler. On the head are four black longitudinal stripes, which are only

faintly visible in dried specimens. A black line, also on each side of the thorax, continuous with a line of the same color along the sides of the wing-covers. Body above black, with indications of two rows of pale spots. Underside pale brown with a broken, blackish, spot-like stripe on each side. In the male the pale portion of the under side of the body is usually reduced to a stripe along the middle. The ovipositor is straight and pointed obliquely upwards, and is about as long as the hind femora. Spines on tibiæ of hind legs rather long. The wing-covers in the male are as long or almost as long as the abdomen, and in the female they are about half as long. The hind wings are over twice the length of the wing-covers, and project beyond like tails.

Length from 9-11 mm.; ovipositor, 8 mm.

Nemobius fasciatus, form *vittatus* Harris.

This form only differs from *fasciatus* in having the hind wings aborted; in color, size and markings it is the same.

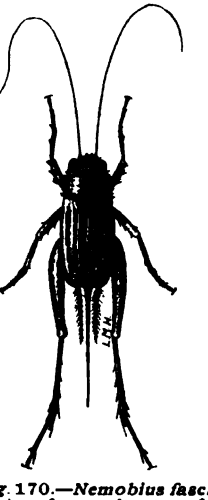


Fig. 170.—*Nemobius fasciatus*, form *vittatus*, female. Original.

It is very abundant in open woods and meadows near by, and is found from July until severe frost. Even in early winter, during warm days and in sunny spots, these insects are active. Like the larger insect forming the genus *Gryllus* they are chiefly solitary and nocturnal, yet may be seen in large numbers together in fields and during the day. They are very pugnacious, and not alone fight among themselves but savagely bite a straw if irritated with it. Especially during their love season they are very quarrelsome, and pitch into each other while keeping up a constant stridulation. Prof. Scudder gives the following pleasing account of the sounds made by this species, which is shown in fig. 170:

"The chirping of the striped cricket is very similar to that of the black field cricket; and may be expressed by *r-r-r-u*, pronounced as though it were a French word. The note is trilled forcibly, and lasts a variable length of time. One of these insects was once observed while singing to its mate. At first the song was mild and frequently broken; afterwards it grew impetuous, forcible and more prolonged; then it decreased in volume and extent until it became quite soft and feeble. At this point the male began to approach the female, uttering a series of twittering chirps; the female ran away, and the male, after a short chase, returned to his old haunt, singing with the same vigor but with more frequent pauses. At length finding all persuasions unavailing, he brought his serenade to a close."

Fig. 171.—*Nemobius* spec., female. Original.

Fig. 171 shows another *Nemobius*, a few of which were found in Minnesota.

Nemobius exiguus Scudder.

THE LESSER STRIPED GROUND-CRICKET.

This also occurs in Minnesota, and is found in company with *vittatus*, from which it may be known by its much smaller size, lighter color, and by the last two segments of the maxillary palpus being white. Its ovipositor is much shorter, being only one-half to two-thirds the length of the hind femora, whereas in *vittatus* it is fully as long.

Length of body, male, 7 mm., of female, 8 mm.; of hind femora, 6 mm.; of ovipositor, 3-4 mm.

Nemobius socius Scudder.

A few very small crickets were captured near the electric light in St. Paul. Prof. Bruner pronounced them to be this species, which is, however, a southern one.

GENUS *Gryllus* Linnæus.

Body short; head large and globose; eyes large and rounded; antennæ thread-like, longer than the body; thorax broader than long, about as wide as the head; hind femora powerful, well developed and adapted for leaping; hind tibiæ with a double row of long spines growing longer towards the tip; anal cerci long and tapering; ovipositor as long or longer than the abdomen; wing-covers as long or shorter than the abdomen, bent down at the sides. Wing-covers of male provided with a well-developed organ for stridulation; hind wings as long, longer or shorter than the abdomen, sometimes aborted.

Fig. 172—*Gryllus abbreviatus*, female, original.

Gryllus abbreviatus Serville.

COMMON CRICKET.

Head, thorax and body shining black. The legs vary from reddish-brown to pitchy-black. Wing-covers fusco-testaceous and as long or nearly as long as the abdomen. Hind wings shorter than the wing-covers. The ovipositor is very long.

Length, 18-23 mm.; length of ovipositor, 18-21 mm.

Illustrated in Fig. 172.

Gryllus pennsylvanicus Burmeister.

Wholly shining, jet black, covered with a very fine grayish pubescence on the thorax, legs

and underside of body. In older examples this pubescence becomes abraded, and the insect is then very glossy. The wing-covers are as long or more or less shorter than the body, and vary in color from ochraceous brown to pitchy black. The hind wings are shorter, or as long, or extend considerably beyond the wing-covers, as tail-like projections.

Length, 10 to 20 mm.; ovipositor, 12 to 15 mm.

This description includes a number of forms or varieties. *G. luctuosus* Serv. is the form with the hind wings projecting like tails beyond the wing-covers; *G. neglectus* Scudder is the form with the wing-covers as long or shorter than the abdomen in the female and as long as the abdomen in the male; *G. nigra* Harris is the form with a somewhat shorter ovipositor. This insect is not common in Minnesota.

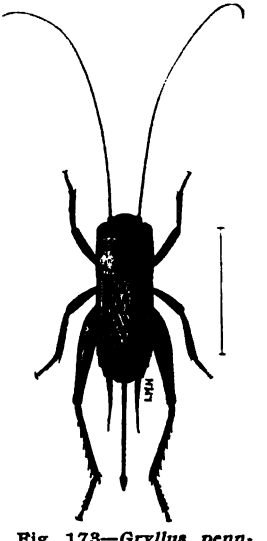


Fig. 173—*Gryllus pennsylvanicus*, female, original.

Fig. 173 shows a female of *Gryllus pennsylvanicus*, and Figs. 174 and 175 both sexes of *Gryllus assimilis*.

No doubt other species occur in our fauna, but they have not as yet been studied. Many of the immature crickets hibernate under stones and other shelters; if they are placed together in a box they speedily fight and the weaker ones are eaten.

There is, however, an European species that is getting too common in some houses, so that complaints are made about it by tenants. This is the European House-Cricket, or "Cricket of the hearth."

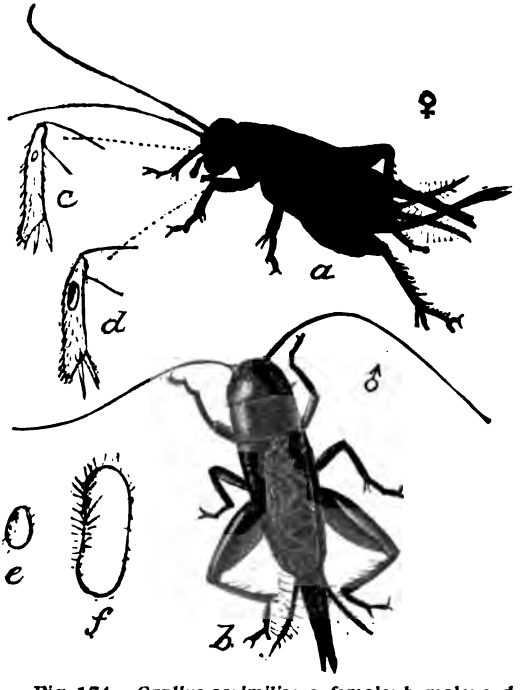


Fig. 174.—*Gryllus assimilis: a*, female; *b*, male; *c*, *d*, fore tibiæ, inner and outer views, showing drums of ear; *e*. and *f*, drums or tympana. Enlarged. From "Household Insects," by Div. of Entomology, Dept. Agriculture.

Gryllus domesticus Linn.

EUROPEAN HOUSE-CRICKET.

Pale brown, with chestnut-brown markings on the head and thorax. The wing-covers extend to the end of the abdomen, and the hind wings extend considerably beyond. It is illustrated in Fig. 176.

Length, 21 mm., ovipositor, 12 mm.

All crickets are musicians, that is the males. Prof. Comstock writes: "During the latter part of the summer and in the autumn, the air is filled with the cries of the crickets. With care it is easy to observe these little fiddlers calling their mates. The common field-crickets lurk in

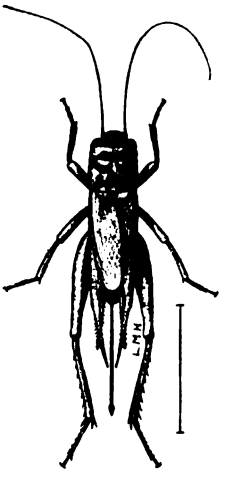


Fig. 176—*Gryllus domesticus*, female, original.

holes in the ground and under stones, or, emerging from these retreats, run through the grass in search of food. At the season indicated above, the male crickets spend much time at or near the entrance of their burrows, making their peculiar calls. So intent upon this are they, that by moving quietly one can approach sufficiently near to watch them carefully. And even when they are disturbed they retreat into their holes only for a short time, if all remains still. At night they can be observed by means of a lantern, as light does not disturb them. In order to understand the manner of making these calls, it is necessary to study the structure of the tegmina, which in the males (Fig. 175, b) differ greatly from the simple form seen in the

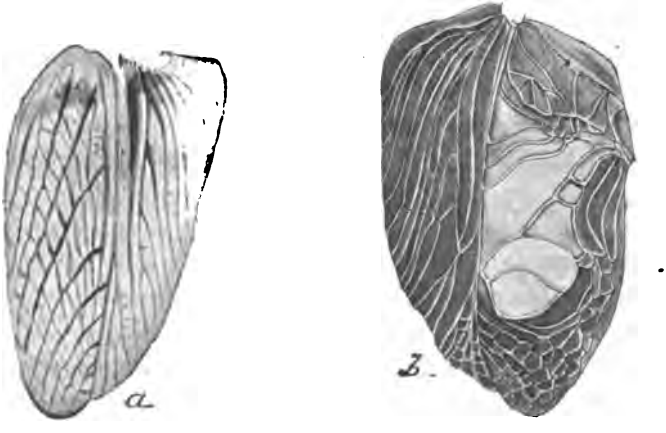


Fig. 175,—*Gryllus assimilis: a*, wing of female; *b*, wing of male, showing the more irregular and coarser veins. Enlarged. From "Household Insects," by Div. of Entomology, Dept. Agriculture.

female (Fig. 175, a)." As has been mentioned elsewhere, only the tegmina of the males are used to produce sounds. When the cricket wishes to make his call, he elevates his tegmina

at an angle of about forty-five degrees with the body; then holding them in such a position that the scraper of one rests upon the file of the other, he moves the tegmina back and forth laterally, so that the file and scraper rasp upon each other. This throws the tegmina into vibration, and produces the call.

Crickets, and especially the House Crickets, may readily be destroyed by taking advantage of their liking for sweet liquids, and any vessel containing beer or other fluids placed about will usually collect and drown large numbers of these insects. They can also be killed by distributing uncooked vegetables, as ground-up carrots or potatoes, which are strongly poisoned with arsenic. Of course great care must be exercised in the use of any poison in and about dwellings.

The sub family *Œcanthinæ* is represented by a single genus.

GENUS *Œcanthus* Serville.

Thorax elongated, narrow, sides deflexed, anterior portion somewhat narrower than the posterior portion. Antennæ about twice as long as the body. Hind legs long and slender, with weak spines on the tibiæ. Wings of female wrapped around the body. Wing-covers of male flattened, transparent, much firmer and broadly spread out, causing such a difference of appearance between the two sexes that collectors consider them frequently widely different species.

The members of this genus are well known insects, usually called "tree-crickets." They are delicate yellowish-green or greenish-white insects found abundantly about low bushes and tall plants. They are strictly arboreal. About the time that our golden-rods are in full bloom these insects can be found upon almost any of these plants, and usually in pairs. They remain almost motionless in such places during the day, but become very active during the night. Though belonging to plant-feed-

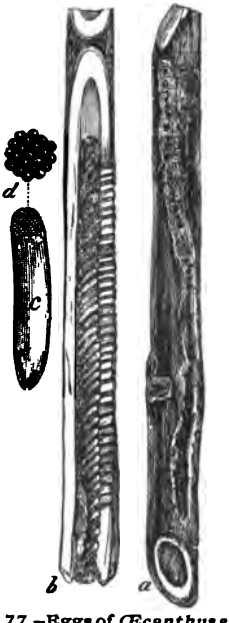


Fig. 177.—Eggs of *Œcanthus spec.*, *a*, twig showing punctures; *b*, twig split open to show eggs; *c*, a single egg; *d*, cap of egg, enlarged. After Riley.

ing insects they prefer in reality other insects, and especially the injurious plant-lice. They would, consequently, belong to the beneficial insects, if they did not possess the bad habit of selecting the cane of useful plants for the purpose of inserting eggs into them. The female, by means of her strong ovipositor, thrusts her eggs into the pith of the cane selected, and as a large number of eggs are thus laid side by side, as shown in the illustration (Fig. 177), the cane is usually killed beyond this point, and if the insects are at all numerous great injury can be caused. Burning the infected cane early in spring is a good remedy.

Œcanthus niveus DeGeer.

THE SNOWY TREE-CRICKET.

Wholly pale, ivory-white, tinged with delicate green, with two slightly elevated black dots on the under side of each antenna, one on the first and one on the second joint (Fig. 178).

Fig. 178.—*Œcanthus niveus*; two basal joints of antennæ. Original

Top of head and first joint of antenna usually pale yellowish-brown. Tip of ovipositor black. Wing-covers almost twice as long as the abdomen; hind wings as long as the wing-covers. The maxillary palpi are longer in this than in any other species of the genus, and the wing-covers of the male broader in proportion to their length than in any other except *latipennis*. Average length, from head to end of wings, 16 mm.;

body, 11 mm.; width of male wing-covers, 6 mm.; of female, 3 mm.

This is one of the most abundant of our tree-crickets, and can be found during August and September in our gardens and orchards. Even if not seen the insect can not escape detection, as its stridulation is very shrill. Though usually heard at night it is sometimes also heard on cloudy days, but only faintly. This stridulating is continuous, and is a pulsating sound like *re-teat, re-teat,* or *a-beat, a-beat.*

The female of *niveus* cause much injury by ovipositing in the tender canes or shoots of various plants, as the raspberry, grape, plum, peach, etc. Prof. Blatchley counted no less than 321 eggs in a raspberry cane 22 inches in length. The eggs are laid in autumn and at first the injury is shown only by a slight roughness of the bark, but afterwards the cane frequently dies above the puncture, or is so much injured as to be broken off by the first high wind. If the injured and broken canes containing the eggs are collected and burned in early spring the number of Snowy Tree-crickets for that season can be materially lessened. If, however, our trees harbor many leaf-lice it is best not to apply such a heroic treatment; it would be best to bring the canes containing such eggs to places where lice abound; as these crickets possess carnivorous propensities, they can be utilized to greatly reduce the numbers of injurious leaf-lice. Miss Mary E. Murtfeldt, of St. Louis, Mo., has given a most interesting account of some experiments and observations with this insect, and the following extract is given: "Some leaves of plum infested with a delicate species of yellow aphis were put into a jar with the young of *Œcanthus niveus*, but attracted no immediate attention. As twilight deepened, however, the crickets awakened to greater activity. By holding the jar against the light of the window or bringing it suddenly into the lamp light, the little nocturnal hunters might be seen hurrying with a furtive, darting movement over the leaves and stems, the head bent down, the antennæ stretched

forward, and every sense apparently on the alert. Then the aphides provided for their food would be caught up one after another with eagerness and devoured with violent action of the mouth-parts, the antennæ meanwhile playing up and down in evident expression of satisfaction. Unless I had provided very liberally not an aphis would be found in the jar the next morning and the sluggish crickets would have every appearance of plethora."

Œcanthus angustipennis Fitch.

Wholly ivory-white, rather deeply tinged with greenish; wings transparent and sometimes with a pale yellowish-brown patch on top of the head. Head and prothorax less prominent, and the latter much narrowed anteriorly. Antennæ with two elevated black marks on the under side, the one at the first joint hooked at the base, with the hook turned inward and the mark on the second joint oblong. (Fig. 179.) Readily distinguished by the narrowness of the wing-covers of the male, their breadth being just about one-third their length.

Fig. 179.—*Œcanthus angustipennis*—two basal joints of antennæ. Original.

Average length from head to end of wing-covers, 14 mm.; body, 10 mm.; width, 3.5 mm.

This is not a common species, and only a few have been collected during August. It seems to prefer the taller trees, hence is not readily found. Its stridulation is very different from that of *niveus*, being a continuous faint *reeeeeee'*, lasting about five seconds and terminating abruptly, with an equal interval of rest.

Œcanthus faciatus Fitch.

Two forms occur in Minnesota, one of which is very much darker than the other. The species is readily distinguished by the markings on the first two joints of the antennæ. As seen in

Fig. 180.—*Œcanthus fasciatus*, male. Original.

Fig. 182.—*Œcanthus fasciatus*—two basal joints of antennæ of dark form. Original.

Fig. 183.—*Œcanthus fasciatus*—two basal joints of antennæ of light form. Original.

the illustrations (Figs. 182 and 183) these markings are confluent in the darker variety, and well separated in the lighter one. This cricket is always darker in color, varying from a deep black to ivory-white with fuscous markings. Most specimens, however, are greenish-white, with three black stripes on the head and pronotum, and a broad dusky line along the center of the abdomen beneath. The wing-covers of the male are less broad in proportion to their length than in *niveus;* while the ovipositor is longer and more distinctly turned upward at the end. Both sexes are shown in Figs. 180 and 181.

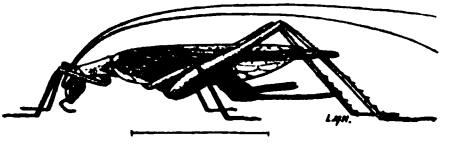


Fig. 181.—*Œcanthus fasciatus*, female. Original.

This is almost as common as the "Snowy Tree-cricket." Its stridulation is a long and comparatively loud continuous whir often lasting several minutes.

Œcanthus latipennis Riley.

Pale yellowish-green, with the wing-covers very much broader in the male than in any other species of the genus. The antennæ are destitute of black marks on the underside of the first two joints, which are characteristic of the other species of *Œcanthus*. The basal joints of the antennæ (Fig. 184) and the top of head are of a distinct pink color. The wing covers extend considerably beyond the abdomen, and the wings in the male are much shorter than the wing-covers, and in the female about as long.

Fig. 184.—*Œcanthus latipennis*—four basal joints of antennæ. Original.

Average length from head to tip of wing-covers of male, 16.19 mm.; width of wing-covers, 7-8 mm.; female, 14-17 mm.; width, 3-4 mm.

This is quite a distinct looking insect, easily distinguished by the pink color of the basal joints of the antennæ and top of head. It is a rather uncommon insect, at least in places visited by the writer. The insect prefers low plants in damp places.

Upon closer search it is very likely that other species of these interesting insects will be found. As a general rule different species do not inhabit the same bushes or trees.

The sub-family *Trigonidiinæ* is also represented by a single genus.

GENUS *Anaxiphus* Saussure.

Somewhat closely allied to *Nemobius* in general appearance, but differing by having the ovipositor sabre-like and curved upwards, with the end compressed. The antennæ are very long, about five times as long as the body, and the spines of hind tibiæ are of equal length. Wing-covers of male almost encasing the abdomen, with a round glassy patch on top near the end of the wing. Hind wings absent.

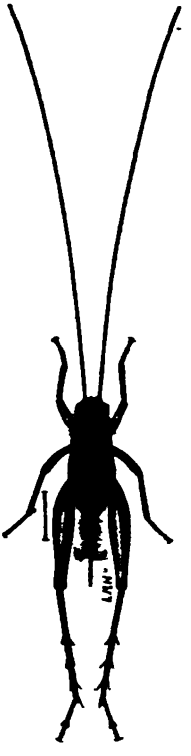


Fig. 185.—*Anaxiphus pulicarius*, female. Original.

Anaxiphus pulicarius Saussure.

Head and pronotum brick-red in color, sparsely clothed with long hairs; wing-covers and legs very light brown; abdomen and ovipositor darker.

Both sexes are wingless, but the wing-covers of the male are well developed, fully covering the abdomen, while those of the female reach but little beyond its middle. The cerci are exceedingly long, tapering, and covered with fine yellow hairs. The hind femora of the males are proportionately much larger than those of the females, as will be seen by the following measurements: Length of body, male, 6.5 mm.; female, 8 mm.; length of posterior femora, male, 6.5 mm.;

female, 6 mm.; length of ovipositor, 3.5 mm.; of antennæ of male, 32 mm.

This insect (Fig. 185) has twice been captured among the tall weeds near the Mississippi River, but is not common. Its habit of living mostly on bushes and rarely on the ground also distinguishes it from the members of the genus *Nemobius*, which all prefer the ground.

The sub-family *Eneopterinæ* is represented in Minnesota by one genus with one species, the *Orocharis saltator* Uhler (Fig. 186). But as this insect belongs in the South, where it inhabits trees and bushes, it is doubtful whether it really occurs here or not. The table of sub-families gives the characters of the genus, to which should be added that no more than two oblique veins traverse the median area of the tympanum of the male tegmina, and are found in the proximal portion only, and that the fore tibiæ possess auditory foramina on both faces. The insect resembles a stout brown tree-cricket.

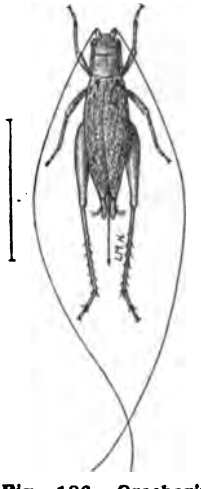


Fig. 186.—*Orocharis saltator*, female. Original.

Fig. 187.—*Field-crickets;* 1 and 2, adults; 4, active pupa or nymph; below 1 cricket's just hatched

EXPLANATIONS

OF

TERMS USED IN TEXT.

A.

A, as prefix of a word means wanting, without.
abbreviated, shortened, not extending to the extremity of a given part.
abdomen, posterior part of the body (Fig. 21).
aborted, imperfectly developed.
abraded, scraped or rubbed off.
acuminate, becoming gradually narrower; tapering to a point; a point lengthened out.
acutely, sharp; sharply pointed.
adult, grown up; sexually mature.
adventitious, accidentally; casually acquired.
alary (*ala*, *alatus*), relating to wings or wing-like parts.
ampliate, enlarged; dilated.
anal, situated at or near the anus.
analogue, differing as to structure but of similar function.
annulus, *annulation*, *annulate*, a colored ring around a body.
ante, a prefix meaning before.
antennæ, two jointed sense-organs situated on the head; feelers (Fig. 21).
anterior, *anteriorly*, near the head; situated more to the front.
anus, the posterior opening of the alimentary canal.
apex, the terminal portion of any organ or part of the body.
aphis, plant-louse.
apical, *apically*, applied to a part rising at the tip of a body.
apodemata, *apodema*, plates of chitine supporting internal organs.
appressed, pressed closely against; fitting closely to.
approximate, near to; near together.
apterous, wingless.
arboreal, living on or among trees.
arcuate, *arcuation*, arched; bowed.
area, *areola*, *areolate*, wing-cells; cellules; the membraneous spaces between the nervures.
articulated, divided into distinct joints.
auditory organ, ear; hearing-organ (Fig. 37, 38).
attingent, touching; coming in contact with.
axillary, arising from the angles, as *axillary vein*.

B.

basalis, basal, relating to the base; arising from the base.
bifid, cleft; cloven in two.
bifurcate, a part not over the half of its length divided into two dull points.
biseriately, in two series.
bullate, a blister (*bulla*); blister-like.

C.

cæcum, cæcal, a tube open at one end only (Fig. 40, 41).
callosity, callosus, an elevated rounded portion of the surface, generally smooth, appearing like a swelling; an elevated substance harder than the surrounding matter.
canthus, one of the upper and lower or interior and posterior extremities of the compound eyes of insects.
cardo, cardines, a hinge (Fig. 27).
carneous, flesh-colored.
carina, carinæ, a keel or ridge.
castaneous, chestnut-brown; bright reddish-brown.
cercus, cerci, the appendages issuing from the sides of the last abdominal segment (Fig. 38).
chitine, the corneous substance of the skin of an insect.
cimeter-shaped, like a short, curved oriental sword.
cinereous, ash-colored; gray tinged with blackish.
clavate, having a thickened, club-like extremity.
clypeus, a part of the head (Fig. 22).
coleopterous, relating to beetles.
colon, largest part of the intestine (Fig. 40, 41).
confluent, running into each other.
concave, when the surface gradually declines toward the center, which thus becomes the deepest.
convex, when the surface gradually rises toward the center, which thus becomes the highest.
cordiform, cordate, heart-shaped.
coriaceous, leather-like, tough and somewhat rigid.
corneous, a horny substance; resembling horn.
corpus adiposum, fatty substance.
costa, median carina of the face; also the front margin of wings and tegmina.
costal, anterior; (margin of wing) (Fig. 33).
coxa, the globular or oblong basal piece of the leg (Fig. 35).
crest, a sharp ridge.
cristate, with a prominent longitudinal carina on its upper surface.
cylindrical, a round body, equally thick throughout.

D.

declivent, steep; precipitous.
decurved, bowed downwards.
deflexed, bent downwards.
depressed, pressed downwards; more or less flattened vertically.
dentate, furnished with a tooth or teeth.
denticulations, with tooth-like notches.
dichromatism, the quality of possessing two color varieties.
digitate, finger-like.
dilated, distended.
dimorphic, existing in two forms.
discoidal area (Fig. page 155).
disk, the middle of a surface; the surface within the margins.
distal, farthest distant, opposite of proximal.
diurnal, active during the day.
dorsal, pertaining to the upper surface.
dorsum, the upper surface or back of thorax, abdomen, etc.

E.

elliptical, elongate-oval.
elongate, more stretched than usual.
elytra, the wing-covers; tegmina; anterior or upper wings (Fig. 33).
emarginate, *emargination*, edged; notched; terminating in an acute notch at tip.
embryo, the living being within the egg (Fig. 5).
ensiform, sword-shaped.
epicranium, the upper part of the head, from the front to the back (Fig. 22).
epimera, narrow or triangular pieces at the sides of the under surface of the thorax (Fig. 31).
episterna, large pieces just in front of the epimera (Fig. 31).
excavate, having a depression.
extruded, thrust out; expelled.
exuded, discharged slowly, through pores, etc.

F.

facets, the surface of the ocelli of the compound eye.
fascia, *fasciæ*, transverse bands or broad lines.
fastigium, the extreme point of the front or apex of the head when it is produced in a conical prominence.
fauna, the animals of a locality.
femora, the thighs (Fig. 35).
fenestrated, with transparent spots like small windows.
ferruginous, rusty-brown; brownish-red with some yellow.
filiform, slender, thread-like.
fissure, crack; crevice.

flabellate, fan-shaped.
flavous, yellow like a lemon or like sulphur.
foramina, *foramen*, opening at an apex; small openings.
fossa, a deep pit or depression serving for the point of attachment of an organ (Figs. 22, 30, 31).
fossorial, fit or used for digging or burrowing.
foveola, a cavity or small depression (Fig. page 156).
front, *frons*, the upper forward part of the head (Fig. 40).
frontal, relating to the front.
fuliginous, sooty; dark brown with a little red.
fulvous, tawny, or light yellowish-brown.
furcula, the process of the last abdominal segment of the male.
fuscous, dark brown; a plain mixture of black and red.
fusion, union.

G.

galea, helmet; a dilated, unarticulated, membraneous piece of the maxilla (Fig. 27).
ganlion, *ganglia*, a nervous mass or enlargement (Fig. 40).
gena, cheek (Fig. 22).
genicular, knee-jointed: bending abruptly in an obtuse angle.
genicular arc, a curved dark marking on the posterior knee-joint.
genital chamber (Fig. 38.)
gibbous, protuberant; marked with elevations.
glabrous, smooth or polished, not hairy.
glaucous, whitish-blue, inclining to gray.
globose, like a ball.
gressorial, fitted for walking.
griseous, light gray (white and black).
gula, throat, concave portion below the head.

H.

hemispherical, shaped like half a ball.
hexagonal, six sided.
hibernate, to pass the winter in seclusion or sleep.
host, the individual furnishing food to a parasite.
humeral, situated on or near a *humerus* or anterior corner of the thorax or wing-cover.
hyaline, transparent with a greenish tinge.

I.

ilium, small intestine (Fig. 41).
imago, an adult insect.
immaculate, not marked.
incrassate, thickened; swollen at some particular point.
included, hidden partly or entirely (the opposite of *extruded*).
infra-ocular, below the compound eyes.

infumate, clouded slightly with brownish-black; shaded as if with smoke.
infuscated, clouded with brown; darkened with a fuscous shade or cloud.
ingluvies, crop (Fig. 41).
inosculate, to unite.
integument, outer covering; skin.
intercalary vein (Fig. on page 155).
internal, inside.
interspace, space between.

J.

joints, segments; places of union.

L.

labial palpus, (Fig. 26).
labium, lower lip (Fig. 26).
labrum, upper lip (Fig. 22).
lacinia, the cutting portion of the maxilla (Fig. 27).
lamina, a callous plate; a hard, slightly elevated surface.
lanceolate, lance-shaped.
larva, the stage in the existence of an insect following the egg-stage.
lateral, laterally, situated on the side.
lateral lobes of the pronotum, the deflexed portions that cover the sides of thorax.
ligula, superior part of the labium (Fig. 26).
line, one-twelfth of an inch.
linear, very slender.
longitudinal, lengthwise.
lozenge-shaped, rhomb-shaped.
luteous, unmixed yellow; color of clay.

M.

maculate, spotted; marked with spots.
malphighian tubes, (Fig. 41).
mandible, hard and horny jaws (Figs. 22, 25).
marginal, situated on or near the margin.
marginate, with an elevated margin.
marmorate, marbled; veined like marble.
maxilla, (Figs. 22, 27).
maxillary palpi, (Figs. 22, 27).
median, medial, occupying the middle.
mediastine, being in the middle.
membrane, membraneous, a thin tissue; consisting of a thin tissue.
mentum (Fig. 26).
mesial, mesially, median; middle; dividing into two equal parts.
mesonotum, the upper or dorsal surface of the mesothorax (Fig. 32)
mesosternum, the under surface of the mesothorax (Fig. 30).
mesothoracic epimeron, (Figs. 30, 31).

mesothoracic episterna, (Figs. 30, 31).
mesothorax, the middle part of the thorax, to which the wing-covers and middle pair of legs are attached (Figs. 30, 31, 32).
metamorphosis, changes an insect undergoes (Figs. 42, 43).
metanotum, the upper or dorsal surface of the metathorax (Fig. 32).
metasternum, the under surface of the metathorax (Fig. 30).
metastethia, metathorax.
metathorax, the posterior part of the thorax, to which the wings and hind pair of legs are attached (Figs. 30, 31, 32).
metastoma, tongue.
metathoracic epimeron, (Fig. 30, 31).
metathoracic episterna, (Fig. 30, 31).
metazona, the posterior part of the pronotum (Fig. on page 156).
millimeter (*mm.*), the thousandth part of a meter, equal to 0.03937 inch, or nearly 1/25 inch.

N.

nebulous, clouded; with uneven, cloudy markings.
nerves, the large ribs or veins of wing and wing-covers, extending from the base towards the apex.
nervules, the smaller connecting veins of the wings and wing-covers.
nocturnal, active at night.
nymph, an immature insect active and feeding in the larval and pupal stage.

O.

obconic, conical, with the vertex pointing downward.
oblique, slanting.
oblong, with the transverse diameter much shorter than the longitudinal.
obsolete, no longer functionally active.
obtuse, *obtusely*, blunt.
ochraceous, brownish-yellow; of the color of ochre.
ocelli, *ocellus*, the three simple eyes (Fig. 22).
occiput, back part of head (Fig. 40).
œsophagus, passage for food to digestive tract (Figs. 40, 41).
omnivorous, eating everything eatable.
oötheca, a case enclosing eggs (Fig. 51).
opaque, without any lustre; impenetrable by light rays.
orifice, an opening.
oval, egg-shaped.
ovarioles, one of the ovarian tubes or glands of which a composite ovarium may be composed.
ovate, egg-shaped.
oviduct, the passage through which the eggs reach the outside.
ovipositor, the organ for depositing eggs (Fig. 39).
oviposition, the act of laying eggs (Fig. 3).

P.

pallid, pallescent, pale or whitish-yellow.
palpi, palpus, articulated and movable organs attached to the maxillæ and mandibles (Fig. 26).
palpiger, a process bearing a palpus (Fig. 26).
pantherine, with markings like those of a panther.
parasite, an animal which grows and lives upon another.
patellar, pertaining to the *patella* or knee-cap.
pectus, the breast or under surface of the thorax.
pellicle, a thin skin or film.
pellucid, transparent; translucent, but not necessarilly colorless.
penis, the genitals of the male (Fig. 40).
pentagonal, five-sided.
percurrent, running through the entire length.
piceous, piceus, pitchy; the color of pitch.
pigment, coloring matter.
pilose, having long, sparse hairs.
pit, a pronounced cavity.
plane, a level surface destitute of elevations or depressions.
pleurite, lateral sclerites which connect the tergites to the sternites (Figs. 31, 36).
plicate, having parallel raised lines; plaited or folded.
plumbeous, pale blue-gray, like lead.
podical plates, two plates (Figs. 38, 39).
polygonal, many sided.
post, a prefix meaning behind.
posterior, behind in position.
post-scutellum, (Figs. 28, 32).
prescutum, anterior division of a thorax (Fig. 28).
process, an outgrowth from the body of a sclerite.
pronotum, the shield which covers the front part of the thorax (Fig. 28).
prosternum, the under surface of the thorax (Fig. 30).
prosternal spine, a spine projecting from the underside of the thorax (Figs. 28, 29).
prothorax, the anterior division of the thorax to which the head is joined (Fig. 28).
proventriculus, gizzard (Fig. 41).
proximal, nearest; opposite of *distal*.
prozona, the anterior dorsal part of the pronotum (Fig. page 156).
pubescent, covered with soft, short, and not crowded hair, wool or down.
punctate, punctured; containing numerous small, point-like depressions or *punctures*.
pupa, pupal, the second state of an insect after leaving the egg (Fig. 1, *f*).
pulvilli, pulvillus, the little pads between the claws (Fig. 35).
pyloric, relating to the opening from the stomach to the intestine (Fig. 41).
pyriform, pear-shaped.

R.

radial vein, (Fig. page 155).
rectum, posterior part of alimentary canal (Fig. 40).
reticulate, with net-like veins or markings.
retrorse. pointing backward.
roseate. *rosaceous*, rose-red; a pale blood-red.
rudimentary, not sufficiently developed to be of use.
rufous, *rufescent*, reddish.
rugose, *rugosity*, *rugæ*, wrinkled; wrinkles.

S.

salivary, relating to saliva; secreting or conveying saliva.
saltatorial, fitted for leaping.
scabrous, covered with small, slight elevations; rough like a file.
scraper, a part of the stridulating organ (Figs. 46, 48).
scrobes, pits or depressions in which are placed the bases of the antennæ.
scutel.um, the third division of a thoracic tergite (Figs. 28, 32).
scutum, the second division of a thoracic tergite (Figs. 28, 32).
sebific, fat-secreting.
segment, ring-like division or joint.
semi, a prefix meaning half.
serrate, saw-toothed.
serrations, teeth like a saw.
serrulate, finely serrate; having minute serrations.
setaceous, bristle-shaped.
shrilling organs, (Fig. 48).
sinuate, indented; cut into a series of deep sinuses with a wavy border.
sinus, a curvilinear indentation, more or less profound; an excavation as if scooped out.
solitary, single.
spatulate, paddle-shaped.
speculum, a mirror-like, transparent, shining surface on the tegmina of male grasshoppers and crickets used as a sounding board (Fig. 45).
spermatheca, a receptacle for semen; the seminal receptacle in the female insect.
spinose, armed with spines.
spinulose, furnished with *spinules* or diminutive spines.
spiracle, an external opening of the respiratory system.
spurs, the strong spine at the apex of the tibiæ.
squamæform, shaped like a scale.
sternal plate, the ventral plate of a body segment.
sternum, the ventral part of a body segment.
stipes, the second joint of the maxilla (Fig. 27).
stridulate, to make a shrill sound; to grate, scrape or creak with the stridulating organs.
style, a small non-articulated process near base of abdomen.

styliform, shaped like a style.
sub, a prefix meaning nearly; almost; somewhat; under, etc. It signifies either that the term is not exactly applicable in its strict sense and that it must be understood with some latitude, or that the object described occupies an inferior position, i. e. lower than some other object.
sub-costal vein, (Fig. 33).
sub-median vein, (Fig. 33).
subulate, awl-shaped.
sulcate, grooved; furrowed; marked with broad, concave, parallel lines.
sulcus, a linear groove or channel; a groove-like excavation.
supra, a prefix meaning above.
suture, a seam or impressed line; generally used in reference to the junction of two pieces or plates.

T.

tarsus, tarsi, (*tarsal*), the jointed foot (Figs. 21, 35).
tectiform, ridged in the middle and sloping down on each side.
tegmina, the elytra, fore wings, upper wings or wing-covers (Fig. 33).
tegument, any natural covering or envelope.
tempora, temples; the sides of the head just in front of the eyes.
tergite (*tergum*), the dorsal part of a body segment (Fig. 36).
testaceous, dull yellowish-brown; tile or brick colored.
testes, glands secreting seminal fluids (Fig. 40).
tetramerous, having four joints as the tarsus of some insects.
thorax, the part of the body of an insect to which are fastened wings and legs (Fig. 21).
tibia, tibiæ, the part of the leg between the thigh and the foot (Figs. 21, 35).
trachea, tracheæ, air-tubes.
translucent, transmitting very little light.
transparent, transmitting light.
transverse, crosswise.
tricarinate, having three keels or carinæ.
triquetral, with three flat sides.
trochanter, the second joint of the leg (Fig. 35).
truncate, cut off square at the tip.
tubercle, a little solid pimple or excrescence.
tuberculate, covered with tubercles.
tumid, tumescent, slightly inflated.
tympanum, the membrane closing the ear (Fig. 37).

U.

unarmed, without a spine.
uniarticulate, having but one joint; single-jointed.
ungues, the curved hooks terminating the tarsus (Fig. 35).
ulnar vein, (Fig. on page 155).

V.

vagina, a sheath-like plate enclosing an organ.
valgate, enlarged at the bottom; club-footed.
valves, four horny appendages forming the ovipositor (Figs. 2, 39).
vein, nerves: ribs of a wing (Figs. 33, 34).
veinlets, nervules; very small cross-veins of the wings.
vena radialis, (Fig. on page 155).
venation, method of distribution of veins (Figs. 33, 34).
venter, the inferior portion of the abdomen composed of sternites.
ventral, pertaining to the under surface of the abdomen.
ventriculus, stomach (Fig. 41).
vertex, the front portion of the upper surface of the head between and in front of the eyes (Fig. 40).
viscid, covered with a slimy, sticky, or greasy matter.
vitta, a band: a streak or stripe, of color or texture; a fascia.

W.

wing-covers, front wings; elytry; tegmina (Fig. 33).
wing-pads, undeveloped wings, as in the pupa or nymph.

SUGAR BEETS.

SUMMARY OF INVESTIGATIONS FROM 1888 TO 1898.

HARRY SNYDER.

Nature of the Work.—When the Minnesota Experiment Station was established in 1888, experiments relating to the culture of sugar beets were inaugurated. On account of the unusual interest which is now being taken in the beet sugar industry, it has been deemed advisable to include with the report of the experiments conducted during the past year a brief summary of the investigations of the past ten years. In giving the report, it has been the aim to give information along such lines as the letters received from the farmers of the State have indicated that information is desired.

What is the Sugar Beet?—How does it differ from our ordinary garden beets? Originally the two kinds of beets were identical, but by careful cultivation and selection of seed the sugar beet has been raised from its former condition until it now contains from 15 to 18 per cent of sugar. In the development of the sugar beet, the different types have been built up in the same general way, by breeding and selection, as have the different breeds of cattle. The sugar beet is a type of a highly developed plant.

In order to produce sugar beets of the best quality, the conditions must be favorable as to climate, soil, and rainfall.

Climate—The sugar beet is not like the sugar cane, a tropical plant, but it is a temperate zone plant. Raising sugar beets in Minnesota is not an unreasonable undertaking. A study of the climatic conditions of the best sugar beet sections of Europe shows that the sugar beet thrives

best when the average summer temperature is 70° F. A zone of 100 miles on either side of the 70th isotherm is considered as being the ideal climate for sugar beets. A map prepared by the U. S. Department of Agriculture from the records of the weather bureau shows the 70th isotherm as entering the State a little south of St. Paul, then curving north and leaving the State at about the 44th parallel. As to climate, Minnesota is in the natural sugar beet belt.

Soil.—The sugar beet thrives best on a loam soil which contains a fair amount of sand. The subsoil should contain a fair amount of clay, so as to be able to store up a good supply of water. A high knoll or a low wet place should never be selected for sugar beets. Beets should never be grown on shallow breaking or on new land. A soil after it has been cultivated to a grain crop for a few years and is beginning to get out of condition for grain is in good condition for beets. For the sugar beet, do not select the very richest nor the very poorest land. The sugar beet crop is extremely sensitive to its surroundings. If the soil is too rich, the crop does not ripen properly, the beets grow to an immense size and produce but little sugar.

The Experiment Station has analyzed a great many beets which have not been grown on the right kind of soil. In table No. XLV, sample No. 2865, was grown on muck land; the per cent of sugar it is to be observed is very low. Other examples of unsuitable soils used can be observed from the same table. The mechanical and chemical composition of soils from different parts of the state are given in bulletins No. 30 and 41.

In nearly every part of the state there is good loam soil, resting on a clay subsoil, which is well suited to sugar beet culture.

Rainfall.—For sugar beet production there should be an annual rainfall of at least 25 inches, and 30 inches is not an excessive amount. The amount of water required to mature a crop of sugar beets depends largely upon the

nature of the soil, and the cultivation which the crop receives. If the soil is well stocked with water in the spring, and the crop gets a good start, it will be able to mature during a dry season. During the unusual season of 1894 the last rain during the growing season was May 8; at the Experiment Station the sugar beet crop stood the drought much better than the potato crop. A dry fall is the most favorable for the maturing of the crop. With an abundance of rain in the fall the beets do not mature properly. The rainfall in nearly every part of the state is well suited to the production of this crop. In fact the three most essential conditions for the production of sugar beets of the best quality, viz: soil, climate and rainfall, appear to be properly met in this state.

Beets Grown at the Experiment Station.—During the past eight years the beets grown at the Experiment Station have shown a general average of 15.55 per cent sugar, and a purity coefficient of 85.8. No commercial fertilizers have been used in any of the general culture experiments. It has been the aim to have the conditions as nearly normal as possible. While the general average for the experiment station beets has been 15.55 per cent sugar, the best methods of cultivation have shown a sugar content of over 17 per cent. While it is possible for a single sample of sugar beets to test as high as 20 or 22 per cent of sugar it is seldom that an entire field will be found with so high a yield. The figures given represent the average per cent of sugar in the beet juice. In all of the tests five beets were selected, and in no case has the sugar content been determined from only one beet. By selecting only the very best beets for the test, instead of selecting average beets, it would have been possible to have obtained figures at least 5 per cent higher than those given.

Purity Coefficient—By the coefficient of purity is meant the per cent of solid matter in the juice, in the form of sugar. A purity coefficient of 85 means that 85 per cent of the solid

matter in the juices is sugar. A low purity coefficient is due to the presence of a large amount of solids, not sugar, in the juice. A beet testing 15 per cent sugar, with a purity coefficient of 85, contains 17.65 per cent of solid matter in the juice. 15 of the 17.65 parts, or approximately 85 per cent, is sugar.

For sugar making purposes the beet juice should contain 12 per cent sugar, and possess a purity of at least 80. The average per cent of sugar in the juice for each year has been as follows:

Year.	Sugar. Per Cent.	Purity.	No. of Samples.
1890	13.2	81.1	12
1891	15.	83.3	108
1892	14.9	86.3	73
1893	16.4	85.2	10
1894	17.4	87.6	10
1895	16.6	86.5	10
1896	15.6	82.4	10
1897	16.3	85.6	128
Average	15.55	85.8	361

The results for a number of years are always more satisfactory and valuable than the results for only one year. During the eight years that the beets have been grown at the Experiment Station there have been no losses from drought, blight, or early frosts. Compared with our ordinary farm crops, sugar beets appear to be a perfectly safe crop to grow. This fact is an important one to consider because in many sections of the United States hot winds, extreme drought, and heavy wind storms are factors, which vary from year to year, and might result in frequent and heavy losses.

Factory Tests —In addition to raising and annalyzing the beets, the Experiment Station has also sent them to the sugar factory at Grand Island, Neb. In the fall of 1892 a car load

of sugar beets was sent to the Oxnard Sugar Beet Factory, and paid for on the basis of the sugar present. President Oxnard wrote the following lettter regarding the beets:

"Feb. 24, 1893.

"Director Experiment Station, St. Anthony Park, Minn.

"DEAR SIR:—In reply to your favor, I will say that your beets were most excellent in every respect, both as to size and quality. If this kind of beets can be grown on a large scale there is no doubt whatever of the adaptability of the soil in your neighborhood to the growth and development of sugar beets. The test showed 14.9 per cent of sugar with a high purity co efficient.

"Very truly yours,

"HENRY T. OXNARD."

No better indorsement of sugar beets could be given, as Mr. Oxnard is president of two or three large sugar beet factories in another State, and the Minnesota sugar beets were paid for at the factory on their merits. The year that these beets were sent to the factory, the average of 73 tests at the station was 14.9 per cent sugar, purity 86.3. The results were published in bulletin No. 27 about a month before the receipt of the letter. It is to be observed that the laboratory tests and the factory tests of these same beets were identical.

Beets from other parts of the state have also been sent to the beet sugar factories. In 1892, Mr. Max Wittgas, a German sugar beet expert, spent the season in Anoka county and vicinity conducting experiments. Some of the beets grown under his supervision tested as high as 19 per cent sugar. He reported the conditions for sugar beet culture in this state as very favorable. Two carloads of beets were sent to the Nebraska factories.

Beets Grown in Different Parts of the State.—There have been about a thousand samples of sugar beets raised by farmers in different parts of the state, which have been sent to the Experiment Station for analysis. Including the beets

grown at the experiment station the general average of the entire state for the years 1888 to '98 has been:

Sugar, per cent..... 14.22
Purity, coefficient..... 81.2
Total No. samples tested..... 1351

The average record for each year is as follows:

	1888	1890	1891	1892	1893
Average per cent sugar.....	13.4	12.9	14.1	15.	15.2
Average purity coefficient...	83.1	79.5	80.1	84.6	84.4
Highest sugar content.....	20.3	17.9	20.4	19.1	18.4
No. samples tested.....	111	55	465	185	15

	1894	1895	1896	1897
Average per cent sugar.....	17.2	15.6	13.7	15.
Average purity coefficient.....	86.6	85.6	81.	83.1
Highest sugar content.....	19.4	20.6	18.2	18.3
No. samples tested.....	14	22	25	303

In many cases the samples sent to the Experiment Station for analysis were overgrown and abnormal. A very prevalent idea is, the larger the beet the higher the per cent of sugar. This is erroneous. Large beets weighing 4, 5 and 6 pounds invariably contain *less* sugar than beets weighing 2 or 3 pounds. Many have insisted upon sending the very largest beets for analysis. Poor cultivation and poor sampling have undoubtedly caused the results to be lower than they should be to represent the average. Notwithstanding the fact that many of the beets were grown under poor conditions, and poorly sampled, the results are high.

CONDITIONS WHICH AFFECT THE SUGAR CONTENT OF THE CROP.

Deep Plowing Essential.—In order to produce beets of best quality for manufacturing purposes, the land must be plowed deep. With shallow plowing the beets develop forked roots and grow above ground, which result in lowering both the per cent of sugar and the purity coefficient. Figure No. 188 shows a group of beets which have been grown on shallow plowing. In table No. XLV. will be found results from shallow plowed land. Observe No. 2866 where the beets were planted on unplowed corn land with the result of 11 per cent sugar, and a purity co-efficient of 70. No. 2901, shallow plowing produced beets with 10 per cent sugar, while beets produced from deep plowing yielded 16 per cent sugar.

Deep plowing is the first essential for the production of beets with a high sugar content.

Manuring.—The manuring of the sugar beet crop requires careful consideration. Raw stable manure should not be applied directly to the land unless the land is in a low state of fertility. A heavy application of manure produces a rank growth, poor in sugar. It is better to manure the sugar beet land the preceding year. In a number of instances heavy manuring has resulted in lessening the per cent of sugar. Mr. George McPherta of Mankato, grew sugar beets on three different kinds of land, with the following results:

	Sugar.	Purity.
Old clay land, highly manured	11.9	79.2
New timber land	11.8	72.4
Sandy loam	14.2	82.3

A light application of commercial fertilizers to the sugar beet crop is not so objectionable as stable manure.

Position in Rotation and Draft on Soil.—Sugar beets may follow a grain crop, as oats, provided that the stubble has been fall plowed. In order to produce the beets economically the land should be free as possible from weed seed. Sugar beets may follow a corn crop which has been manured. It is not desirable to have sugar beets follow potatoes. At the present time but few of the soils in this state require manuring in order to produce sugar beets; in a few years, however, manure will be required. Sugar beets remove about the same amount of fertility from the soil as the potato crop.

Depth of Planting.—The seed should not be planted too deep. Our best results at the Experiment Station have been obtained where the seed was planted one-half to three-quarters of an inch. When the seed is planted too deep the plants are unable to produce a normal amount of sugar. No. 2902 is an excellent example of the effects of deep planting. The seed was planted five inches in a rich river bottom soil. The result was 10 per cent sugar.

Distance Between Rows.—At the Experiment Station the best results have been obtained when the beets were planted in rows 18 inches apart, and the beets 4 to 5 inches apart in the row. The distance between the rows depends largely upon the condition of the soil. If the soil is in a high state of productiveness close planting is more essential than if the land is in a low state of productiveness. With a poor soil there is not enough plant food to support a heavy crop and the beets should be farther apart. With average soil closer planting is necessary in order to prevent the beets from growing too large. In the experiments for 1897 the highest results, 18.5 per cent sugar, and 92.5 purity, were obtained from beets planted in rows eighteen inches apart and four inches apart in the row. The lowest results were obtained when the rows were 30 inches apart and the beets 10 inches apart in the row. The difference was decidedly in favor of the close planting. Our experience last year has emphasized the fact that close planting on a good

soil gives the best results. It is more essential that the beets be close together in the row, than that the rows be close together. When the rows are too far apart it gives about the same result experienced with the outside row of any crop. No. 2880 is an excellent example of what follows from having the beets too far apart,—a large beet with a low per cent of sugar and purity. Many of the beets which have been sent in to the station have been grown in rows 36 inches or more apart. Some of the beets look well, but when cut open they are found to be hollow, coarse and pulpy, and when analyzed they are deficient in sugar. Shallow plowing and planting in wide rows have been the two greatest factors which have reduced the results. Deep plowing and close planting should be the rule.

Date of Seeding and Quantity of Seed Per Acre.—The seed should be sown at about the same time as corn. It is not wise to sow the seed as early as April 1st because the young plant will be too weak to produce a full harvest of sugar. Later seeding is preferable. May 15th to 25th, depending upon the season, are safer dates for seeding. Seeds were sown at the Experiment Station last year (1897) at three different dates, May 15, May 27 and June 5. When the beets were tested Sept. 21 there was practically no difference as to the maturity. The plots planted June 5 contained as much sugar as those planted at earlier dates. The past season was however, an unusually late one. It may require two weeks or longer for the beets to get well out of the ground. The seed should be sown at the rate of 18 to 20 pounds per acre. The object of the heavy seeding is to guard against losses from poor seeds and insects, and to obtain a thick stand of young beets so as to have a good stock to select from when the beets are thinned out.

Cultivation.—The cultivation should begin as soon as the beets are well started. If the land is weedy the cultivation must be started before the beets are up. In thinning the beets in the row, it should be the aim to save the vigor-

ous plants rather than to have the beets exactly 4 or 6 inches apart in the row. If for example at the four inch distance there should be a sickly yellow plant while at the six inch space there is a rich green vigorous one, weed out the four inch sickly one and save the healthy six inch one. The weeding between the rows can be done with a horse hoe provided you have a small sure footed animal that can walk between the 18 or 20 inch rows. The work between the beets in the row must be done by hand. In fact there is a great deal of hand hoeing in raising sugar beets. The beets must be kept free from weeds, otherwise the crop will not develop the requisite amount of sugar. As a general rule, the better the cultivation the higher the per cent of sugar in the crop. The sugar beet crop responds generously to good cultivation. Sample No. 2881 was from a quarter acre plot on which had been expended only 20 minutes labor. The beets contained 11.7 per cent sugar. The sugar beet crop can not be neglected and allowed to shift for itself.

The cultivation should be kept up, at intervals of a week or ten days, until about the first of August, or the 15th of August, if the season is backward, or if there is a drouth.

Length of Growing Period.—It takes from 100 to 110 days for a sugar beet crop to mature, depending upon the season and the variety of beets. If the beets are seeded May 20th they will be ready for the factory about Sept. 10th, they will however test the highest about October 15th. The crop is not killed by a light frost. Cool weather is very desirable for maturing. If the fall should be hot and rainy the beets will continue their growth which will result in a lower sugar content.

Maturity.—When the beets are ripe the outer circle of leaves turn yellow, while the central leaves have a yellowish tinge. As soon as the beet has matured it should be harvested to prevent a second growth. In harvesting a furrow

is plowed close to the row so as to loosen the beets, and they are then removed by hand. The crown or top is then removed with a sharp knife and the beet is freed as much as possible from dirt. If any part of the beet has grown above ground it should be removed with the crown. The beets may be taken directly to the factory or put in piles or pits and kept in the same way as potatoes. Freezing and thawing of the beets ruins them for sugar making purposes. Special machinery has been devised for harvesting the crop where sugar beet culture is made a regular industry.

Sampling for Analysis.—From five different parts of the plot take one or two average beets. Select beets which are perfectly ripe and those which have grown entirely under ground. Do not select any beets weighing more than three pounds. Beets weighing two pounds are preferable to the very large ones. Beets weighing over three pounds are usually rejected at the factory. Send five or ten beets in a box or basket. Send either by fast freight or express, unless otherwise directed. Label the box, Experiment Station, St. Anthony Park, Minn. If sent by freight, ship to Minnesota Transfer, Minnesota. Put your name and address on the box. The express or freight charges must be prepaid or arrangements made with the railway companies for free transportation. No charge will be made for the analysis. A report will be sent as soon as the beets are tested.

The Station desires to keep a complete record of all samples tested, and in order to make the record complete the following questions should be answered:

1. Date of planting.
2. Source of seed.
3. Size of plot.
4. Character of soil.
5. How Deep was the ground plowed?
6. How much cultivation did the beets receive?
7. Distance between rows.
8. Distance between the beets in the row.

9. Total weight of beets raised on plot.

10. What proportion of the beets were under 3 pounds in weight?

11. How much labor expended on plot?

12. Date of harvest.

13. What crop was raised on the land the preceding year?

14. How much rain was there during the growing season?

15. Are you favorably impressed with your experience in raising sugar beets?

16. Name and address.

Cost of Production.—From the most reliable reports received from farmers who have raised sugar beets it appears that from 12 to 15 days' labor must be spent on an acre of beets. The cost of the seed and the team labor makes the total cost from $30 to $35 per acre. If the land is very weedy the cost of production is greater. In order to raise an acre of sugar beets about $30 worth of labor must be expended. The beets yield on an average about 14 tons per acre. In exceptionally good years the yields have been as high as 20 tons per acre. During poor years the yields are as low as 8 tons and even less per acre. It costs on an average about $2.25 to raise a ton of beets. The prices paid for beets at the factory vary from $4.00 to $4.50 per ton, depending upon the quality of the beets. President Oxnard, in regard to the cost of production, writes: "The farmers supplying our factories at Grand Island and Norfolk receive all the way from $20 to $100 per acre for their crop of beets, and I should say that the average cost of raising an acre of beets was from thirty to forty dollars. So you will see that some made as high as fifty to sixty dollars per acre, while others actually lost money growing beets."

An acre of beets is as much as any one should attempt the first year. Two acres of sugar beets well cultivated and kept clean means a good deal of labor. Where there is no

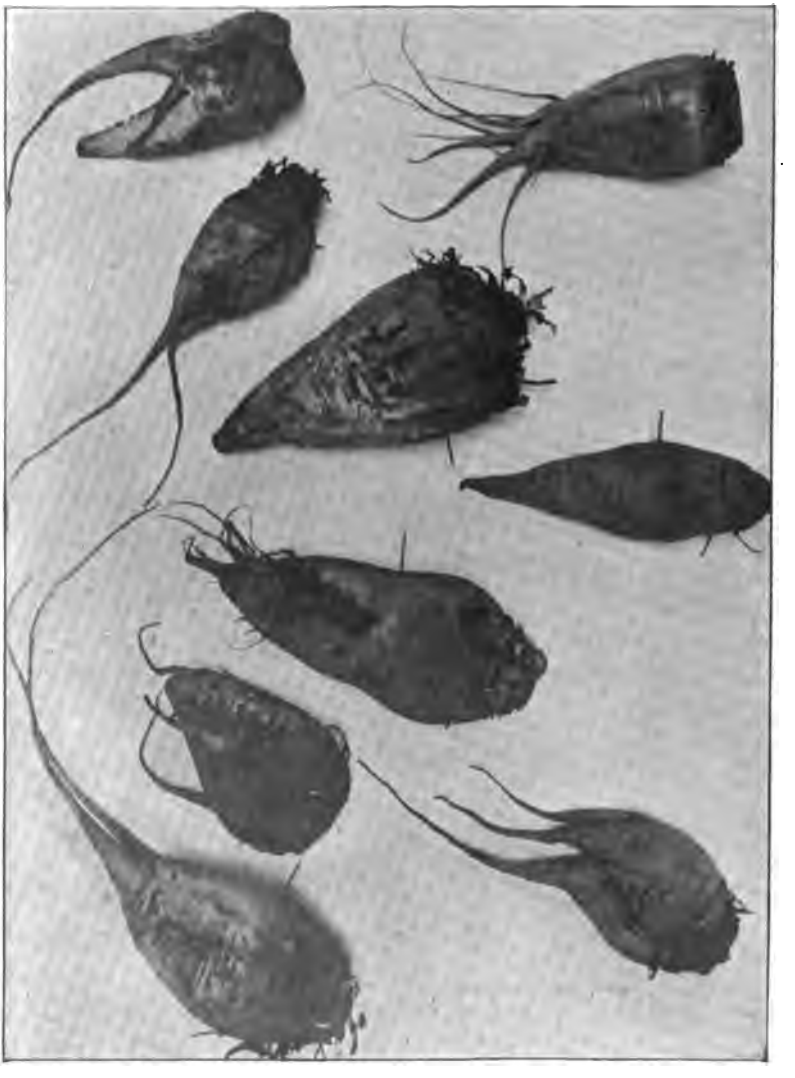


Fig. No. 188.—Samples of Poor Beets Raised on Shallow Plowed Land.

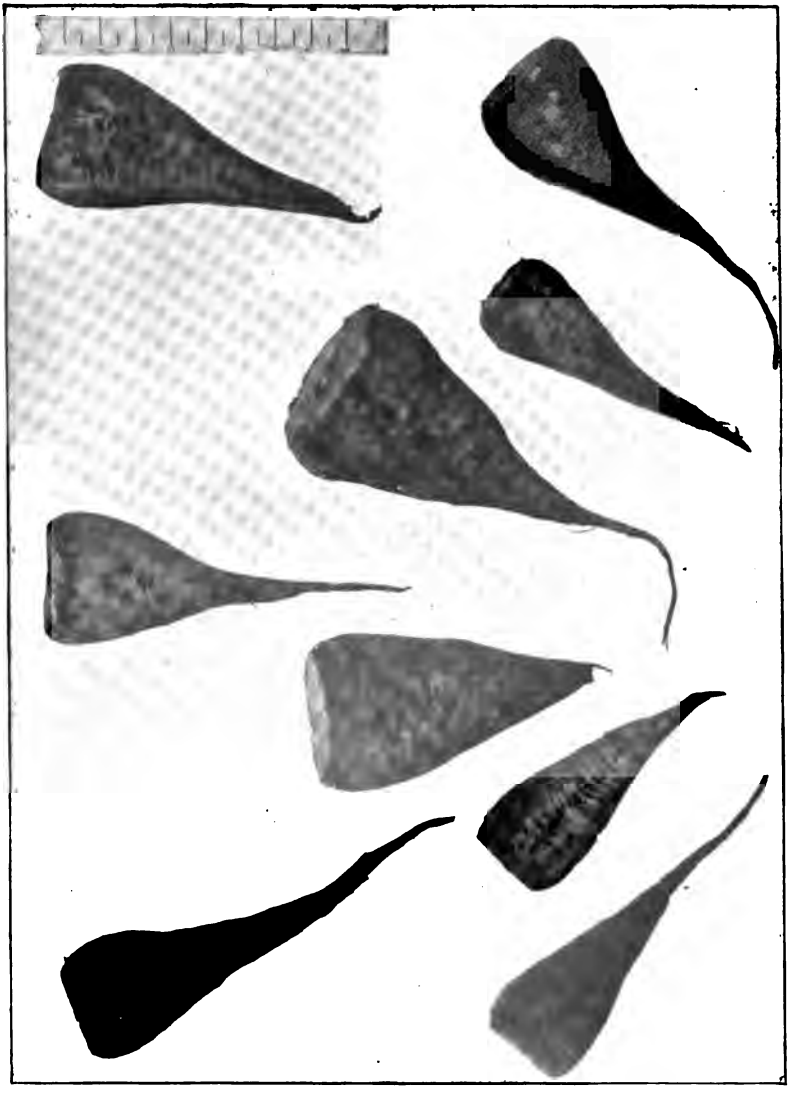


Fig. No. 189.—Samples of Good Beets Raised on Deep Plowed Land.

market for the crop, there should not be more than a quarter acre raised for experimental purposes. Where stock is kept the feeding value of the quarter acre of beets will more than repay the labor expended in producing the beets. When properly used sugar beets are a most excellent crop for dairy and all kinds of stock.

How Does the Sugar Beet Crop "Fit In" With Other Farm Work?—The main work of weeding comes in June and July. This is usually a time when the ordinary farm work is not so pressing. The main work comes after seeding is well over and before harvest time. With good management the sugar beet crop can be made to fit in well with other farm crops so as to make an even distribution of labor during the summer. The time for harvesting and marketing however, comes when there is an ample supply of fall work.

How Many Beets Would It Require to Supply a Factory?—An ordinary sugar beet factory would require from 200 to 300 tons of beets per day. President Oxnard states that "a factory should run at least 75 days" per year. "You ought to have a guaranty of at least 2,000 acres before attempting to locate a beet sugar factory." An average beet sugar factory will produce from 3,000 to 5,000 tons of sugar per year, varying with the capacity of the factory and the length of the working season. A sugar beet factory will require from 25,000 to 30,000 tons of beets per season. The usual price paid for beets ranges from $3.75 to $4.50 per ton. In a locality where a sugar beet factory is located from $100,000 to $120,000 are annually paid for beets.

According to statistics compiled by the U. S. Department of Agriculture, there are annually consumed in the United States 2,000,000 tons of sugar. About 10 per cent of this amount is produced in this country, while 90 per cent is imported. The amount of beet sugar produced is about 35,000 tons. According to these figures it would require about 14 beet sugar factories to supply the State of Minnesota with sugar.

Importance of Producing Good Beets.—There is nothing gained by sowing a row or two of sugar beets in some neglected corner of a field and having the beets analyzed. By so doing an injustice is done to the locality. When beets are grown for a sugar factory, a contract is signed to the effect that the beets will be cultivated in a certain way, which is practically the method outlined in this bulletin. There have been so many experiments made with sugar beets that it is only a waste of time and energy for any one to attempt to produce them according to some preconceived idea or notion. Table XLV shows the results of neglecting to observe the necessary conditions of cultivation; the reader will observe that the violation of the essential conditions for cultivation is invariably followed by a low per cent of sugar and purity. It is not the desire of the Experiment Station to increase the number of such tests as those recorded in table No. XLV. Not all of the beets in table No. XLIV. were grown, in all respects, under the best conditions. There are many localities in the State which have a lower average than they should have, simply because of poor cultivation. It is an injustice to any locality of the State where it is hoped to establish a beet sugar factory, to have beets analyzed which have not been properly grown.

EXPERIMENTS AT ALBERT LEA, 1897.

The experiments at Albert Lea were conducted by the Albert Lea commercial club. An expert sugar beet agriculturist was employed by the commercial club. Seed was procured and distributed to about 100 farmers The beets were grown under the supervision of Mr. H. F. Postel, who went from farm to farm during the growing season, giving instructions as to how the beets should be cultivated. The experiments were conducted in a thoroughly systematic way. The Experiment Station took no part in the work except to analyze the samples of beets when received.

At about the same time that samples were sent to the Experiment Station for analysis, a few duplicate samples were sent to the U. S. Department of Agriculture for analysis. Mr. Morin, secretary of the committee, reports that the results from the two sources were as follows:

	Analysis made by Minn. Experiment Station.		Analysis made by U. S. Department of Agriculture.	
	Sugar. Per Cent.	Purity.	Sugar. Per Cent.	Purity.
G. L. Slocum	13.1	73.	13.	75.6
T. A. Vandergrift	14.2	84.	14.6	82.5
Peter Jensen	13.5	78.2	13.	75.
Lorin Blackmer	13.8	83.6	15.3	85.
A. C. Wedge	14.6	93.6	14.4	84.7
Nels Ackland	16.	84.7	15.3	85.5
W. R. Sweet	14.1	84.3	16.4	85.4
J. Howe	14.6	84.4	16.	82.
K. K. Nystrom	13.7	80.5	15.8	86.3
Average	14.3	82.9	14.6	82.4

Table No. XLIII. Sugar Beets from Albert Lea.

Name.	No.	Sugar. Per Ct.	Purity.	Weight of Beet. Ozs.
Nels Ackland	2910	16.	84.7	19
A. H. McNeal	2911	14.9	84.1	19.6
Chas. Peterson	2912	16.	88.3	18.8
F. F. Carter	2913	15.	88.8	13.
John Adams	2914	15.8	82.3	18.
Robert Nelson	2915	14.5	80.1	17.4
H. P. Jenson	2916	15.2	83.	19.
M. L. Whalen	2917	14.7	80.	17.
Jacob Baker	2918	14.6	83.9	18.
F. G. Haupt	2919	14.3	90.	22.
George Peterson	2920	15.7	82.5	20.2
T. A. Vandergrift	2921	14.	81.	17.6
Peter Peterson	2922	14.7	83.4	17.4
John Bergland	2923	16.	84.7	13.2
Peter Burgland	2924	15.1	83.4	12.8
E. R. Sweet	2925	15.1	88.9	20.
George Widman	2926	14.9	87.6	19.6
Dr. A. C. Wedge	2927	14.6	93.6	18.6
J. E. Pratt	2928	15.5	82.5	13.2
Morin & Mason	2929	14.7	84.	16.4
J. G. Forest	2930	15.5	92.2	19.5
John Barron	2931	15.9	90.	17.6
Dr. A. H. Street	2932	15.9	84.	11.6
M. A. Teslow	2933	14.	86.9	12.4
P. R. Howgard	2934	15.1	86.7	12.8
Joseph Brabec	2935	14.2	80.2	23.2
Joseph Cypera	2936	14.	83.3	13.2
J. Howe	2937	14.6	84.4	17.
Chas. Brickson	2938	14.	84.8	13.6
Ole Ofstehauge	2939	14.7	89.6	16.8
Joseph Chrs	2940	14.3	85.5	13.
Andrew Larsen	2941	15.2	85.4	15.
Hans Carlson	2942	14.1	81.1	18.4
Loren Blackmer	2943	13.8	83.6	17.4

Table No. XLIII—Continued. Sugar Beets from Albert Lea.

Name.	No.	Sugar. Per Ct.	Purity.	Weight of Beet. Ozs.
W. R. Sweet	2944	14.1	84.3	17.6
J. P. Larson	2945	14.8	84.1	20.
Nels Johnson	2946	13.3	80.5	11.6
Peter Larson	2947	14.4	83.2	16.4
N. P. Sorseson	2948	14.4	88.8	16.8
A. O. Backen	2949	14.	89.7	14.4
C. H. Dills	2950	13.8	86.8	13.8
C. H. Dills, 2d	2951	13.2	77.	20.
Chris. Schmidt	2952	13.3	84.2	16.
Louis Nelson	2953	13.9	80.8	14.6
Fred Lenchman	2954	13.1	78.5	17.5
G. D. Slocum*	2955	13.1	73.	18.
F. D. Drake	2956	13.1	80.9	17.
N. P. Nilson	2957	13.7	80.5	10.4
L. P. Larson	2958	13.	83.5	17.6
Andrew Skaugh	2959	13.4	79.	25.6
E. E. Budlong	2960	14.1	90.	15.2
Peter Jenson	2961	13.5	78.2	12.4
K. K. Nystrom	2962	13.7	80.5	13.4
Frank Sipple	2963	13.5	84.8	16.
A. A. Flatten	2964	13.5	76.	11.6
Otto Otterson	2965	13.7	81.5	14.4
Nels Anderson	2966	13.7	82.5	17.8
J. R. Page	2967	13.1	76.3	9.
O. Buckley	2968	12.8	80.	14.6
G. H. Trescott	2969	12.	80.	24.
T. E. Noble	2970	14.3	85.	17.6
E. B. Randall*	2971	11.5	75.7	14.6
Peter Nelson	2972	13.6	85.	18.4
Henry Bunghart	2973	12.6	82.4	14.4
Henry Wittmer*	2974	11.6	80.6	17.6
W. H. Walker	2975	12.5	73.5	22.
John Kraushaw	2976	12.	80.	12.
J. Finefair*	2977	11.	80.	15.2

Table No. XLIII.—Continued. Sugar Beets from Albert Lea.

Name.	No.	Sugar. Per Ct.	Purity.	Weight of Beet. Ozs.
John Emmerson*	2978	11.6	73.9	14.4
Louis Fogel	2979	12.8	81.5	26.
Christ Yorke*	2980	11.5	70.1	28.
N. J. Judd*	2981	11.5	72.	16.
C. M. Nelson*	2982	11.5	77.	22.8
Henry Harrison	2983	12.8	75.	13.2
G. O. Foss	2984	12.5	77.8	16.2
Neem Nelson*	2985	11.	73.	16.
B. Porter*	2986	11.5	74.	20.
G. W. Anderson	2987	12.5	78.5	21.2
John E. Ellingson*	2988	10.	71.4	16.4
Chris Jenson	2989	12.	73.	14.4
John Larson	2990	12.9	80.	19.6
	2991	15.1	86.	19.
	2992	14.2	84.	21.4
Average		13.8	82.0	16 6
Average, Omitting*		14.2	83.1	

Table No. XLIV. Sugar Beets Grown by Farmers in Different Parts of Minnesota in 1897.

No.	Name.	Date of Analysis.	Post Office.	County.	Source of Seed.	Soil.	Sugar Per cent.	Purity.
		1897						
2834	Frank Schroeder.....	Oct 28,	Mankato,	Blue Earth,	State	new land, low	12.5	80
2835	Morgan Brooks	Oct. 28,	"	"	"	black sand	11.5	79.3
2836	Wm. Lieferman.....	Oct. 28,	"	"	"	loam	13.3	80.2
2837	John C. Wise.....	Oct. 25,	"	"	"	black loam	12.1	80
2839	W. J. Crandall.....	.....	"	"	"	black muck	13.6	80.1
2840	Sanford Billings.....	Oct. 28,	"	"	"	black loam	13.1	80.1
2841	John F. Johnson.....	....	"	"	"	clay and sand	12.2	79.2
2842	E. R. Bohan.....	Oct. 28,	"	"	"	black loam	14.1	83.8
2843	D. L. Rose..	Oct 28,	"	"	"	sandy silt	12	78
2844	D. R. Brooks.....	Oct. 28,	"	"	"	sandy loam	11.4	75
2845	Gottlieb Chostag.....	Oct. 28,	"	"	"	black loam	13.2	84.6
2846	I. G. Pelton.....	Nov. 1,	"	"	"	sandy soil	13.6	80
2847	A. G. Pirath.....	Nov. 1,	"	"	"	black loam	13.6	80
2848	Wm. Leefield.....	Nov. 1,	"	"	"	black soil	13.9	81.9
2852	Fred Shoenbeck.....	Nov. 1,	"	"	"	black soil	12.5	80
2802	Ed. A. Page.....	Nov. 27,	Carleton,	Carleton,	.....	.....	14.1	80.1
2803	John Jarchow.....	Nov. 13,	Harris,	Chisago,	.....	sandy	12	80.1
2804	C. B. Kittredge.....	Jan. 1,	Glyndon,	Clay,	State	.....	13.5	84.5
2805	J. W. Strathern.....	Oct. 28,	Rich Valley,	Dakota,	.....	sandy loam	12	80
2806	F. Stevenson.....	Nov. 8,	Dodge Center,	Dodge,	State	clay	13	80

Table No. XLIV.—Continued.

Sugar Beets Grown by Farmers in Different Parts of Minnesota in 1897.—Continued.

No.	Name.	Date of Analysis.	Post Office.	County.	Source of Seed.	Soil.	Sugar Per cent.	Purity.
		1897						
2807	John A. Gardner.....	Nov. 13,	Chatfield,	Fillmore,	State	black loam	14	80
2808	Hanson Bros.....	Oct. 28,	Hartland,	Freeborn,	Nebraska	" "	13.9	84.2
2809	J. J. Dack.....	Oct. 10,	Stanton,	Goodhue,	C. & G. W. Ry Co.	" "	15	78.5
2810	Jos. Alexander.....	Oct. 16,	Stanton,	Goodhue,	C. & G. W. Ry Co.	sandy loam	15	80
2811	Hans Halverson.....	Oct. 16,	Dennison,	"	C. & G. W. Ry Co.	black & sandy	12.8	81.5
2812	J. H. White.....	Dec. 20,	Crystal,	Hennepin,	.....	.....	13.8	80
2813	H. W. Richardson.....	Oct. 10,	Edina Mills,	"	Northrup & King	black loam	14.3	78
2814	A. C. Carter.....	Nov. 8,	Springvale,	Isanti,	Exp. Station	sandy loam	16.3	84.8
2815	P. K. Haserud.....	Oct. 28,	Madison,	Lac que Parle,	State	upland prairie	15.3	82
2816	Solomon Sears.....	Oct. 28,	Dawson,	" "	"	prairie	13	80.2
2817	Joseph Dale.....	Oct. 28,	"	" "	"	"	16.2	83.9
2818	John Olson.....	Oct. 28,	"	" "	"	"	16.1	81
2819	P. K. Haslerud.....	Oct. 10,	Madison,	" "	"	"	16.6	84.7
2820	E. E. Sterling.....	Oct. 28,	Elysion,	LeSeur,	Exp. Station,	very s'dy lo'm	14.8	83.1
2821	Geo. E. Brockman.....	Nov. 2,	Fairmont,	Martin,	.....	sandy loam	14.1	85
2858	F. A. Smith	Nov. 8,	Austin,	Mower,	.....	.....	14.1	83.2
2855	A. W. Edson.....	Nov. 8,	"	"	.....	.....	13.8	80
2854	J. Siavan.....	Nov. 13,	"	"	.....	.....	14.2	86
2822	Arthur Seebeck.....	Oct. 21,	Sutton,	"	.....	.....	14	81.9
2823	N. Kneif	Nov. 13,	St. Peter,	Nicollet,	State	clay loam	13.2	81.5

Table No. XLIV.—Continued.

Sugar Beets Grown by Farmers in Different Parts of Minnesota in 1897.—Continued.

No.	Name.	Date of Analysis.	Post Office.	County.	Source of Seed.	Soil.	Sugar Per cent.	Purity.
		1897						
2824	N. Knclf.....	Nov. 13,	St. Peter.	Nicollet,	State	black loam	12.5	81
2825	S. J. McKenzie.....	Oct. 16,	Adrian,	Nobles,	"	loam	14.2	80
2826	Jos. Ouradnik.....	Oct. 16,	roun.	Pine,	....	sandy loam	15.5	84.5
2827	W. H. Wiebler.....	Oct. 20,	Be. Plaine,	Scott,	.....	....	12.8	81
2829	F. J. Steidl.....	Sept. 16.	Wheaton,	Traverse,	Exp. Station	rich bl'k loam	13.4	81.2
2830	Henry L. Pengilly.....	Oct. 16,	Mazzeppa,	Wabasha,	Dept. of Agr.	loam–clay sub	12.3	8[illegible].8
2831	P. M. Clark.....	Oct. 28,	St. Paul Park,	Washington,	" "	sandablk lo'm	18	90.1
2832	John Holmquist.....	.....	Otisville,	"	Germany,	sandy loam	16.9	84.4
2868	Frank Yahnke.....1	Oct. 14,	Winona,	Winona,	....	sandy loam	14.9	84.6
2869	" " 2	Oct. 14,	"	"	.....	.....	14	87.5
2870	W. R. Christie.....	Oct. 28,	"	"	.....	loam	14	81.9
2871	S. Reisinger	Oct. 28,	Stockton,	"	.....	blkl'm,cl'ysub	12.7	77.6
2872	E. Ellinghuysen.....	Oct. 28,	"	"	Exp. Station	s'dy " "	13.1	80.9
2873	A. Enterlee..... ...	Oct. 28,	"	"	Washington	" " "	12.1	82.3
2874	J. A Moore.....	Oct. 28,	"	"	.....	" " y.c.sub	12.9	81.6
2877	William C. Moore.....	Nov. 26,	"	"	Oxnard	loam and clay	17.8	82.4
2878	Benj. Sherry.....	Nov. 29,	"	"	.....	bl'k s'dy loam	13.4	78
2879	Chas. Pierce.....	Nov. 29,	"	"	.....	" " "	12.3	.....
2833	H. Mueller.....	Oct. 28,	Buffalo,	Wright,	....	.....	13.9	79
				Average.....			13.8	81.4
				General Average of all Samples for 1897.....			15	83.1
				General Average of Experimental Station Beets for 1897.....			16.3	85.6

Table No. XLV. Sugar Beets Grown in Different Parts of the State under Poor Conditions of Cultivation. 1897.

No.	Remarks	Per Ct. Sugar	Purity Coefficient	Size Oz.
2880	1 row only. Beets 12 inches apart in row. Beets hollow	12.0	78.0	52.0
2881	20 minutes' labor expended on plot. Poor seed	11.7	80.7	20.0
2882	1 row only. 6 to 8 inches apart in row. Flax grown on land year previous	13.0	78.8	21.0
2883	Rows 3 feet 8 inches apart. Beets 6 inches apart in row. Unripe and hollow	11.5	78.7	24.0
2884	Rows 2 feet apart. Beets 8 inches apart in row. Shallow plowing	11.5	74.4	15.0
2885	Rows 20 inches apart. Beets 8 to 9 inches apart in row	11.5	70.0	27.0
2886	Beets green and hollow. Grown above ground	11.9	73.6	56.0
2887	All hollow and rather scabby. 2 rows only and 20 inches apart	11.0	72.8	27.0
2888	Hollow and unripe beets. Shallow plowing	7.8	65.0	62.0
2889	Wilted, green, hollow; shallow plowing	11.0	75.0	12.0
2890	Beets unripe	10.0	72.0	18.0
2891	Hollow and unripe; grown above ground	11.0	80.0	31.0
2892	1 row only. Beets hollow	11.3	83.1	30.0
2893	Unripe and badly wilted	7.5	76.0	48.0
2894	Rows 28 inches apart, beets 10 inches apart in row. Grown in garden. Beets large	14.0	75.7	49.0
2895	Beets unripe and hollow; shallow plowing	12.0	81.3	48.5
2896	Shallow plowing. Beets grown above ground	12.7	76.0	30.0
2897	Shallow plowing. Beets grown above ground	11.9	74.0	25.0
2898	Beets unripe and hollow. Old worn land	11.4	81.4	29.3
2899	Green and hollow	9.5	75.4	38.0
2900	Hollow and unripe beets	10.5	72.9	24.5
2901	Shallow plowing	10.0	78.7	16.0
2902	Grown on heavy river bottom soil. Seed planted 5 inches deep. Beets unripe	10.0	74 1	18.0
2865	Grown in muck; rows 30 inches apart	10.5	71.	49.0
2856	Rows 24 inches apart; beets 10 to 24 inches in row	13.2	74.6	46.0
2857	Rows 30 inches apart; beets 3 to 15 inches in row	12.6	77.	.....
2868	Rows 36 inches apart; beets 10 inches in row	11.5	75.8	60.0
2862	Rows 30 inches apart; beets 8 inches in row	12.2	73.9	50.0
2864	Shallow plowing and heavy manuring	10.7	72.6	66 0
2866	Unplowed corn land	11.0	70.0	.....
2828	Low land; new breaking	12.5	77.0	.....

About 50 more examples could be added.

Table No. XLVI. Sugar Beets Grown at Experiment Station, 1897.

[NOTE.—Each number represents a separate plot. Five beets were taken for every test.]

Laboratory Number.	Distance Between Rows.	Distance between Beets in row. Inches.	September 21.		October 28.		Average Weight. Ounces.	Source of Seed.
			Sugar in Juice.	Purity	Sugar in Juice.	Purity		
2760	Fourteen inches.....	4	14.2	86.1	17.6	85.8	10.	State.
2761	" "	4	14.8	87.2	17.	85.	12.8	U. S.
2762	" "	6	13.3	84.7	18.3	87.1	12.	State.
2763	" "	6	14.1	82.9	17.2	87.	11.2	U. S.
2764	" "	8	13.3	88.7	17.3	87.3	12.8	"
2765	" "	8	13.5	85.	14.9	84.	19.2	State.
2766	" "	10	13.5	84.4	16.	87.4	15.	"
2767	" "	10	13.4	80.3	15.1	81.	14.8	U. S.
2768	Eighteen "	4	14.	85.4	18.5	92.5	12.8	"
2769	" "	4	13.	86.7	17.5	87.	10.	State.
2770	" "	6	12.3	85.4	16.7	87.	12.8	"
2771	" "	6	13.7	87.2	16.8	86.6	11.2	U. S.
2772	" "	8	15.8	84.1	16.6	88.8	14.4	"
2773	" "	8	13.4	86.5	15.8	87.	11.2	State.
2774	" "	10	13.5	84.9	16.3	86.2	14 4	U. S.
2775	" "	10	13.2	86.8	15.7	81.8	11.2	State.
2776	Twenty-four "	4	13.1	84.5	16.2	84.8	16.	"
2777	" "	4	12.6	87.5	16.8	85.3	17.6	U. S.
2778	" "	6	13.2	84.7	15.2	88.	12.8	"
2779	" "	6	13.4	86.5	16 2	94.2	14.8	State.
2780	" "	8	12.9	87.8	17.1	87.7	14.4	"
2781	" "	8	13.8	87.5	15.5	86.5	16.	U. S.
2782	" "	10	12.5	86.8	16.6	86.9	14.4	"
2783	" "	10	11.7	84.8	17.	87.2	13.2	State.
2784	Thirty "	4	12.4	84.4	15.8	82 3	15.2	"
2785	" "	4	12.9	84.9	16.	85.1	16.	U. S.
2786	" "	6	12.	82.8	16.4	89.1	14.8	State.
2787	" "	6	13.5	88.8	15.6	84.7	13.4	U. S.
2788	" "	8	12.1	85.2	15.2	82.2	14.4	State.
2789	" "	8	12.9	82.7	15.6	83.9	13.4	U. S.
2790	" "	10	12.5	85.6	15.5	83.4	14.8	"
2791	" "	10	10.8	80.	14.2	78.	18.4	State.

Table No XLVII. Beets Seeded at Different Dates.

No.	Date Seeded.	September 21.		October 28.		Average Weight.
		Sugar in Juice.	Purity.	Sugar in Juice.	Purity.	Ounces.
2792	May 15,	14.	81 9	16.5	86.	12.8
2793	" 15,	13 9	86.9	16 5	86.4	11.2
2794	" 27,	13.7	85.6	16.6	84.3	15.2
2795	" 27,	13.1	87.3	17.7	86.	10.
2796	June 5,	14.2	88.8	18.2	87.	11.6
2797	" 5,	13.8	85.2	17.9	86.	10.8

Table No. XLVIII. Summary Table.

	No. of Plots.	No. of Tests.	Sugar. Per Cent.	Purity. Per Cent.	Average Weight. Ozs.
Highest Results.—Rows 18 inches apart and beets 4 inches in row	.....	.....	18.5	92.5	12.8
Lowest Results.—Rows 30 inches apart and beets 10 inches in row	.....	.....	14.2	78.	18.4
Average of rows 24 and 30 inches apart and beets 4 to 6 inches in row	8	16	16.	86.1	15.1
Average of rows 24 and 30 inches apart and beets 8 to 10 inches in row	8	16	15.8	85 5	14.9
Average of rows 14 and 18 inches apart and beets 8 to 10 inches in row	8	16	15.9	85.4	14.1
Average of rows 14 and 18 inches apart and beets 4 to 6 inches in row	8	16	17.4	87.3	11.6

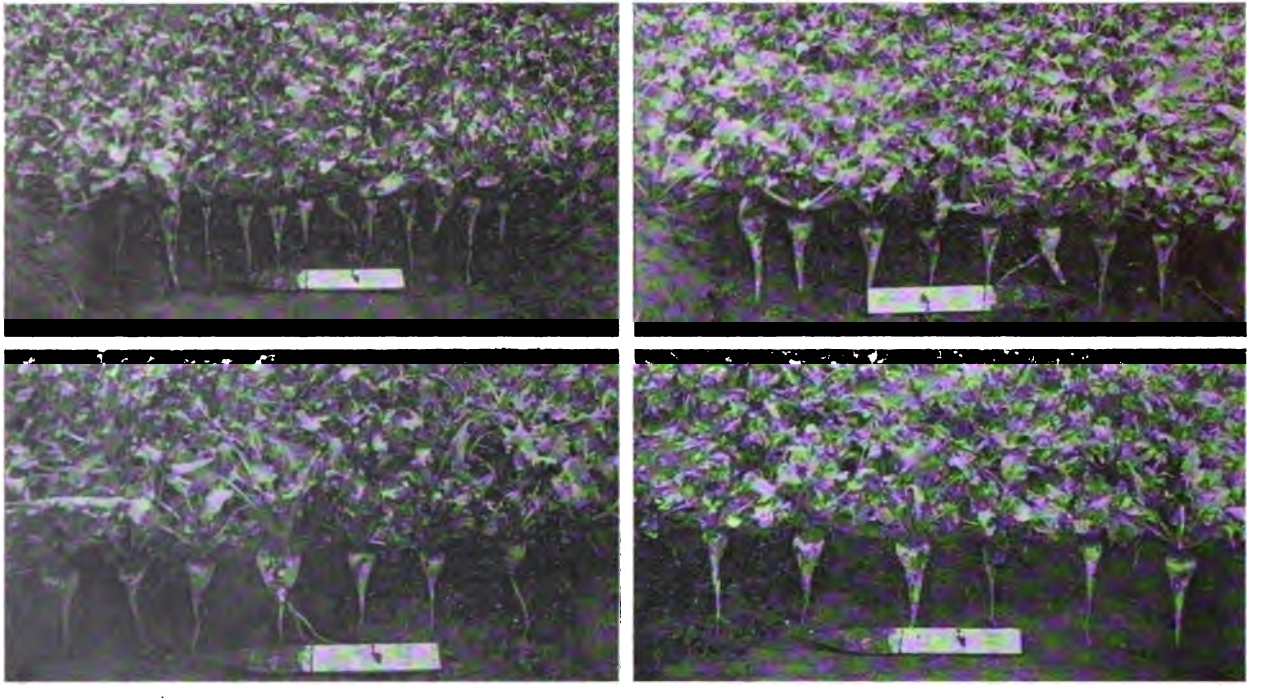
FIELD EXPERIMENTS.

ANDREW BOSS.

During several years past the Experiment Station has raised sugar beets to study various problems concerning their growth. The University Farm has proven to be well adapted to their production. The yields, per cent of sugar and the purity of the juice are all sufficiently high to make the yield per acre of sugar large. The value per acre of the marketable crop is sufficient to make it quite remunerative to the farmer at the ordinary prices paid per ton for good beets at sugar factories. Thirty tons, more or less, have been fed each winter, to dairy and beef stock and to sheep, with satisfactory results, though at a valuation which would not pay for raising such small roots as are best to raise for a sugar factory. While these sugar beets have contained nearly as much dry matter per acre as large stock beets, it costs considerably more per acre to produce them. They will not pay as well to raise for feed as will the large varieties of mangels.

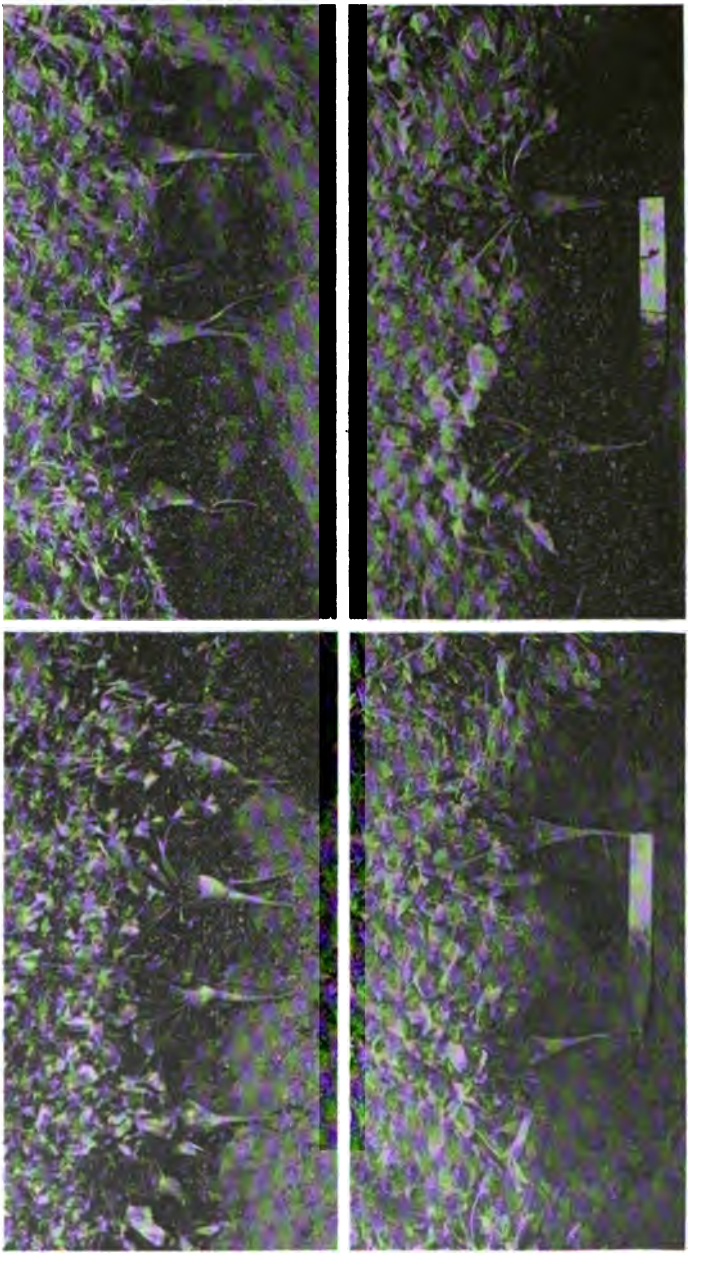
Distance Apart to Grow For Sugar.—In 1897 an experiment was undertaken to study the best distance apart to grow sugar beets when grown for sale at a sugar factory. The yield per acre, the per cent of sugar, the purity of the juice, the form of the roots and the labor required to grow the roots were the factors especially noted. The factory desires beets of good form, with a high percentage of sugar and with high purity, that the expense of manufacture may be at a minimum. The farmer seeks also large yields per acre and he wishes to grow them in such manner that the expense of cultivating and harvesting may be as low as is practicable with the best results.

For the purpose of this work thirty-two 1-20th acre plots were used. On plots numbered from 7 to 22 seed of



Sugar Beets.—Rows 18 inches apart, beets 4 inches apart in the row.
Sugar Beets.—Rows 18 inches apart, beets 8 inches apart in the row.

Sugar Beets.—18 inches apart, beets 6 inches apart in the row.
Sugar Beets.—18 inches apart, beets 10 inches apart in the row.



Sugar Beets.—Grown in rows 14 inches apart.
Sugar Beets.—Grown in rows 24 inches apart.

Sugar Beets.—Grown in rows 18 inches apart.
Sugar Beets.—Grown in rows 30 inches apart.

the Klien Wanzlieben variety, obtained from the Norfolk Beet Sugar Co., Norfolk, Nebraska, was planted on May 15th. On May 20th these plots were duplicated as to manner of planting, but seed of the same variety imported from Germany was used. The soil is a medium rich one of mixed clay and loam with good drouth resisting qualities.

Plan of the Experiment.—On plots numbered 7, 8, 9 and 10 the seed was planted in rows 14 inches apart. The beets on plot 7 were thinned to 4 inches apart in the row; on plot 8, to 6 inches apart; on plot 9, to 8 inches apart, and on plot 10, to 10 inches apart. All other conditions were alike so far as is known. On plots 11, 12, 13 and 14 the beets were planted in rows 18 inches apart and thinned to 4, 6, 8 and 10 inches apart respectively in the row.

On plots 15, 16, 17 and 18 the rows were made 24 inches apart, and on plots 19, 20, 21 and 22, 30 inches apart. These also were thinned to 4, 6, 8 and 10 inches apart in the row.

Preparation of the Soil.—The land on which these beets grew had raised a crop of oats the year previous and was plowed 6 inches deep in the fall. In the spring of 1897 well rotted barnyard manure was applied at the rate of twenty tons per acre and the land again plowed at a depth of nine inches. The spring plowing was done early and the land was harrowed frequently until the beet seed was planted. This frequent cultivation killed the weeds which had germinated early and gave the beet seed when sown, an even chance with the weeds.

Sowing the Seed.—The seed was sown with a small garden seed drill at the rate of eighteen pounds per acre on the plots with rows 18 inches apart. Proportionately more seed per acre was sown on the plots with rows 14 inches apart and proportionately less on the plots where the rows were 24 and 30 inches apart. A stand may be obtained by sowing as little as ten or twelve pounds of seed per acre, but to make sure of a stand and to insure against

the necessity of transplanting, which is an expensive operation, it is better to plant eighteen to twenty pounds. The seed was planted three-fourths of an inch deep.

Cultivation.—Cultivation was started as soon as the plants could be seen in the row. A two-wheel hand hoe was first run over the row and immediately followed by cultivation between the rows with a fine toothed cultivator. A hand machine was used between the fourteen and eighteen inch rows and a horse cultivator between the twenty-four and thirty inch rows. This plan of cultivation was followed until the beets were large enough to thin out. The cultivator was run rather shallow to avoid bringing new weed seeds to the surface and yet deep enough to preserve a dust blanket one and one-half to two inches deep.

Thinning the Beets.—When the beet leaves were two to four inches in length the beets were "bunched" by cutting out sections with narrow hoes, and then thinned by hand. Any weeds found in the row were pulled out at the same time. After the thinning had been done the cultivation given was largely with horse cultivators, except where the rows were fourteen inches apart. One hand hoeing was given the entire field after the beets were thinned.

Harvesting the Beets.—When the beets were mature they were pulled by hand using a potato fork to loosen them in the soil. They were topped as soon as pulled and carried into piles and covered to prevent wilting and sunburning. After standing in piles for a few days, samples were taken for analysis and the beets were hauled to the barn for cattle feed.

The Results.—Table XLIX. is a statement of the manner of planting the Nebraska seed and gives the yields of the individual plots of that variety.

Table L. in a like manner gives the results of the trial of the German seed planted five days later.

In Table LI. are given the average results of the dup-

licate plots. It will be seen by Table LI. that the highest per cent of sugar was obtained from beets planted in rows eighteen inches apart and thinned to four inches in the row. The largest yield of beets per acre was obtained where they were planted in rows eighteen inches apart and thinned to eight inches in the row. The highest purity was reached in the plots where the rows were eighteen inches apart and thinned to four inches. The largest cash return per acre was made from rows eighteen inches apart and thinned to four inches in the row. From a study of the entire table and records at hand it is quite apparent that the best economic results were produced by planting the beets in rows eighteen inches apart and thinning to six or eight inches in the row. Planting in rows fourteen inches apart and thinning to four, six or eight inches apart gave nearly equally good results as did also planting in eighteen inch rows and thinning to four inches in the row. The additional amount of hand labor necessary in rows too narrow to allow of horse cultivation and in thinning, weeding and harvesting the smaller beets grown under these conditions is very expensive, and reduces considerably the net value of the product to the farmer.

Table LII. shows that in the averages of eight plots of each of the fourteen, eighteen, twenty-four and thirty inch rows and including all distances apart in the row, there was practically no difference between the fourteen and eighteen inch rows; the per cent of sugar, the purity of the juice and the yield of beets and of cash from these plots being nearly the same. There was a considerable reduction in the per cent of sugar, yield of beets, and cash yield per acre in the plots where the rows were twenty-four inches apart, while the purity remained about the same. In the plots with rows thirty inches apart both yield and quality were lower.

By consulting Table LIII. we find that there was little difference in the averages of plots where the beets were grown four, six and eight inches apart in the row. Ten

inches apart in the row were evidently too far apart for the largest yield of cash and for the highest purity.

As there appears from this trial to be no direct advantage in planting the beets in fourteen inch rows nor of leaving beets closer than six or eight inches apart in the eighteen inch rows, economy of labor would dictate that for our conditions we plant the rows eighteen inches apart and thin the beets to five to seven inches apart in the row.

TABLE XLIX. Results when Sugar Beets are Planted at Various Distances.

Plot No.	Distance apart in the row. Inches	Distance between rows. Inches.	Form of Roots.	Smoothness of Roots.	Per cent Sugar.	Purity	Yield per Acre.	
							Beets, Tons.	Value.
7	4	14	65	rough.	17.0	85.0	16.8	$67.20
8	6	14	60	"	17.2	87.0	16.1	64.40
9	8	14	55	medium.	17.3	87.3	17.6	70.40
10	10	14	50	smooth.	15.1	81.0	17.1	68.40
11	4	18	65	"	18.5	92.5	15.3	61.20
12	6	18	55	"	16.8	86.6	15.5	62.00
13	8	18	45	medium.	16.6	88.8	15.7	62.80
14	10	18	45	smooth.	16.3	86.2	16.4	65.60
15	4	24	50	"	16.8	85.3	14.7	58.80
16	6	24	45	"	15.2	83.0	16.3	65.20
17	8	24	40	"	15.5	86.5	16.6	66.40
18	10	24	40	"	16.6	86.9	14.9	59.60
19	4	30	55	"	16.0	85.1	15.8	63.20
20	6	30	50	medium	15.6	84.7	14.1	56.40
21	8	30	40	"	15.6	83.9	17.1	68.40
22	10	30	35	smooth.	15.5	83.4	15.6	62.40

Table L. Results when Sugar Beets are Planted at Various Distances.

Plot No.	Distance apart in the row. Inches.	Distance between rows. Inches.	Form of Roots.	Smoothness of Roots.	Per cent sugar.	Purity	Yield per acre.	
							Beets Tons.	Value
23	4	14	45	very smooth.	17.6	85.8	17.6	$70.40
24	6	14	50	smooth.	18.3	87.1	16.3	65.20
25	8	14	45	very smooth.	14.9	84.0	16.2	64.80
26	10	14	40	"	16.0	87.4	16.7	66.80
27	4	18	40	smooth.	17.5	87.0	17.1	68.40
28	6	18	35	medium.	16.7	87.0	17.8	71.20
29	8	18	35	smooth.	15.8	87.0	19.6	78.40
30	10	18	35	"	15.7	81.8	17.9	71.60
31	4	24	30	"	16.2	84 8	15.8	63.20
32	6	24	35	medium.	16.2	94.2	16.4	65.60
33	8	24	30	"	17.1	87.7	15.6	62.40
34	10	24	30	"	17.0	87.2	16.9	67.60
35	4	30	35	smooth.	15.8	82.3	17.3	69.20
36	6	30	30	medium.	16.4	89.1	18.6	74.40
37	8	30	25	"	15.2	82.2	18.0	72.00
38	10	30	25	smooth.	14.2	78.0	15.9	63.60

Table LI. Sugar Beets. Average of Two Trials.

Average of Two Trials. Plots No.	Distance apart in row. Inches.	Distance between rows. Inches.	Form of Roots.	Per cent Sugar.	Purity	Yield per acre. Tons.	Value per acre.
7 and 23...	4	14	55	17.3	85.4	17.2	$68.80
8 " 24	6	14	55	17.7	87.0	16.2	64.80
9 " 25	8	14	50	16.1	85.7	16.9	67.60
10 " 26	10	14	45	15.6	84.2	16.9	67.60
11 " 27	4	18	52	18.0	89.8	16.2	64.80
12 " 28	6	18	45	16.8	86.8	16.6	66.40
13 " 29	8	18	40	16.2	87.9	17.6	70.40
14 " 30	10	18	40	16.0	84.0	17.1	68.40
15 " 31	4	24	40	16.5	85.1	15.2	60.80
16 " 32	6	24	40	15.7	88.6	16.3	65.20
17 " 33	8	24	35	16.3	87.1	16.1	64.40
18 " 34	10	24	35	16.8	87.1	15.9	63.60
19 " 35	4	30	45	15.9	83.7	16.5	66.00
20 " 36	6	30	40	16.0	86.9	16.3	65.20
21 " 37	8	30	32	15.4	88.1	17.5	70.00
22 " 38	10	30	30	14.9	80.7	15.7	62.80

TABLE LII.—Sugar Beets. Distance Apart of Rows.

Average of Eight Plots.	Per cent Sugar.	Purity.	Beets, per Acre. Tons.	Value per Acre.
Rows 14 inches apart	16.7	85.5	16.8	$67.20
Rows 18 inches apart	16.7	87.1	16 9	67.60
Rows 24 inches apart	16.3	87.0	15.9	63.60
Rows 30 inches apart	15.6	84.8	16.5	66.00

TABLE LIII.—Sugar Beets. Distance Apart in the Row.

Average of Eight Plots.	Per cent Sugar.	Purity.	Beets, per Acre. Tons.	Value per Acre.
Thinned to 4 inches in row	16.9	86.0	16.3	$65.20
Thinned to 6 inches in row	16.6	86.8	16.3	65.20
Thinned to 8 inches in row	16.0	87.2	17.0	68.00
Thinned to 10 inches in row	15.8	84.0	16.4	65.60

PROPOSED EXPERIMENTS FOR 1898.

During the coming year it is desired to continue the experiments in the culture of sugar beets. The general plan of the work will however be somewhat different from the plan pursued in former years. The United States Department of Agriculture has requested the co-operation of the Minnesota Experiment Station in sugar beet experiments, and the director of the station, W. M. Liggett, has been appointed a special agent of the department in sugar beet investigations. A limited quantity of seed has been supplied the station on the conditions stated in the following communications:

UNITED STATES DEPARTMENT OF AGRICULTURE,

DIVISION OF CHEMISTRY.

WASHINGTON, D. C., FEB. 1st, 1898.

COL. WM. M. LIGGETT, Director,
St. Anthony, Park, Minn.

Dear Sir:—For many years the department of agriculture and many of the experiment stations of the country have been experimenting with sugar beets. In addition to the special plots cultivated at the experiment stations, it has been the rule to distribute packages of seeds promiscuously in all parts of the country. Experience has shown that not more than twenty per cent of the persons who received seed this way follow out the direction for planting and cultivation, and do not take enough interest in the matter to secure samples for analysis.

It is evident that this work, while interesting and valuable from a certain point of view, can never secure the definite knowledge which it is desired to obtain. The time has

come now when it is important that more careful experimental work be done. The secretary of agriculture has designated me to purchase high grade beet seeds for experimental purposes, and to distribute only to the agricultural experiment stations and in such other localities as may be deemed useful.

It is the policy of the department from now on to secure more definite experimental work than has heretofore been possible. We prefer to send a larger quantity of seed to fewer persons and only to those who will sign an agreement, to prepare the soil, plant and cultivate the beets, harvest and weigh them and secure samples for analyses in accordance with specific directions and as far as possible under supervision.

I earnestly urge upon you as a director to pursue the same line of investigation. Instead of sending promiscuously hundreds of packages of seed to different parts of your state, secure pledges from twenty-five reliable farmers who will undertake under your direction to prepare the soil, plant, cultivate and harvest the beets in such a way as to obtain definite knowledge. You will furnish the directions for conducting the work, and if you prefer, you may use those contained in farmers' bulletin 52. It is suggested that the seed be distributed so as to cover as nearly as possible all typical varieties of soil within your state.

The particular data desired is as follows: Character of soil, geological and otherwise; value of soil per acre at market rates; cost of plowing and sub-soiling; cost of preparation of soil for planting; cost of planting; cost of thinning and cultivating and the number of times cultivated and how; cost of harvesting and topping; definite cost of delivering beets at a factory of a distance not more than six miles or at a railroad station of a distance not more than six miles; exact area under cultivation; exact weight of beets harvested; exact weight of beets after removal of the tops.

Wherever possible, the area under cultivation and the weights obtained of harvesting should be checked by a representative of your station or a committee appointed by you. No guess work of any kind should be allowed to enter into the report. Wages of the farmer and team should be charged at the reguar market rates. It is earnestly requested that the greater part of the seeds which we send you, shall be disposed of in the manner suggested.

Very respectfully,
H. W. WILEY,
Chief of Division.

Feb. 14, 1898.

DR. H. W. WILEY,
Chief, Division of Chemistry,
Washington, D. C.

Dear Sir:—Co-operative experiments of the nature mentioned in your letter of February 1st, we believe can be carried out successfully in this state. Your plan meets my hearty approval.

The distribution of packages of beet seed promiscuously is only of value in educating our people how to plant, cultivate and harvest. When instructions were strictly followed, they learned that it required labor and intelligent care to grow sugar beets that would give a high per cent of sugar. Much interest has been taken in sending samples for analysis, but little care has been taken in cultivation and in selection. This is clearly demonstrated by the higher average of per cent of sugar and purity of the three hundred and sixty-one samples made of beets grown on the experiment farm for the last ten years.

There are many localities in the state which are taking great interest in the culture of sugar beets, and there has been some little effort to encourage the building of factories.

The Commercial Club of Albert Lea is taking a great deal of interest in this work, and employed a man last year

to superintend their experiments and expect to do so again this year. Mankato and Austin are also taking an interest in the work, and experiments are being made in connection with the boards of trade. At Winona much careful work has been done. At Madison, and Dawson, in Lac qui Parle county, as well as in many other places in the state there have been both interest and enthusiasm shown in matters pertaining to sugar beets.

We will make a general supervision of the work which you have outlined and will ask those interested at different places in the state to carry out the work under our directions.

Guess work should not be allowed in any experimental work and we will not accept it. I heartily agree with you that a smaller amount of work done thoroughly, will prove to be more satisfactory.

Very respectfully yours,

WM. M. LIGGETT,

Director.

The conditions under which the beets are to be grown are as follows:

1. The soil must be suitable for sugar beet culture, as stated on page 378. The land must be plowed deep, at least nine inches, and if subsoil is hard, a subsoil plow must be used.

2. An accurate account of the time spent in plowing, planting, harvesting, etc., must be kept so that the cost of producing the crop can be accurately ascertained.

3. At least a quarter acre plot must be grown, and a half acre may be grown if desired. The beets must be grown in rows 18 inches apart and from 5 to 7 inches apart in the row.

4. The beets are to be properly cared for and kept free from weeds, and the crop in the fall to be properly harvested and weighed so that all of the data on page 387 can be given.

The general plan is to grow the beets in the same way as if grown for a beet sugar factory. It is believed that if the work is done more systematically that even better results can be obtained than those reported in this bulletin.

GROWING BEETS FOR BEET SUGAR FACTORIES.

Since the preceding bulletin has been prepared for the press I have received a letter from Hon. Henry Keller, general manager of the Minnesota Beet Sugar Manufacturing Co., of St. Louis Park, Minneapolis, Minn., stating that a sugar beet factory will be in operation at St. Louis Park October 1st, 1898, and it is desirable to obtain contracts for growing sugar beets.

He also states that beets properly grown and contracted will be paid for at the rate of $4 per ton, the shipper to pay the freight charges to St. Louis Park at the following rates per ton: 1 to 20 miles, 30c.; 21 to 35 miles, 40c.; 36 to 50 miles, 50c.; 51 to 70 miles, 60c.; 71 to 100 miles, 80c. over the Chicago, Milwaukee & St. Paul and the Minneapolis & St. Louis Railroads. On all other roads $1.75 per carload will be added for switching.

This notice is given that any who desire to grow sugar beets may have an opportunity to grow them for the sugar beet factory.

WM. M. LIGGETT,
Director.

FATTENING LAMBS IN WINTER.

THOMAS SHAW.

This Bulletin contains three experiments. These were conducted during successive winters beginning with that of 1895-96, and they all relate to the fattening of lambs. In Section No. 1 the lambs fed were reared in Minnesota, and in Sections No. 2 and 3 they were grown on the range.

FATTENING MINNESOTA LAMBS.

SECTION NO. 1.

In the experiment conducted in feeding lambs at our Station during the winter of 1894 and '95, screenings was the principal grain food fed. Prior to that time the writer had not been able to find any experience in our state in finishing lambs entirely on coarse grains other than screenings. The marked relative adaptability of this food for finishing sheep and lambs had already been determined in a general way by the success which had attended such feeding at the stockyards. To further determine the value of screenings for fattening uses in a more precise and elaborate manner seemed to be the ambition of some experimenters, by first analyzing them, and then by feeding them when so analyzed. But the single experiment above referred to soon convinced the writer that experimentation with screenings would not result in any great good. They were a quantity so variable as to render it impossible to classify them, and therefore impossible to convey to the average mind any adequate idea of the different kinds of screenings. No two samples could be found that were alike; while some samples were almost as valuable as wheat in their food constituents and for feed-

ing uses, other kinds were but little better than chaff. The only real tangible good therefore that would seem to arise from experimenting with them further would be to show the farmer the value of the food which he was giving away every year. This had already been demonstrated by the almost exclusive use that had been made of them in fattening sheep at the stockyards. The presence of screenings in quantities so large was not creditable to the farming of the state. It spoke of slovenly and careless methods of cultivation. To spend much time therefore in experimentation with a by-product, the very existence of which in such quantities was a stigma on our agriculture seemed out of place. The Station that did so would unquestionably be better employed in teaching the farmer how not to grow weed seeds than how to feed them when grown.

It was determined, therefore, in the meantime to drop farther experimentation in feeding screenings to sheep and lambs, and to commence a series of experiments that would cover a number of years in ascertaining the relative and also the intrinsic value of the various coarse cereals grown in the state for such a use. The chief of these are corn, barley, oats and flax, all of which grow in fine form within our borders. Heretofore the surplus of all these grains had been shipped over our eastern borders every year in the trail of mill feed sent in enormous quantities in the same direction. These experiments, therefore, were planned in the hope of doing something that would tend to divert this interminable and regretful overflow to the feed yards of Minnesota farmers.

Time Covered by the Experiment.—The preparatory feeding began Dec. 23, 1895, and covered a period of 7 days. The experiment proper began Dec. 30 and ended March 16, 1896, thus covering a period of 11 weeks or 77 days. On March 17 the major portion of the lambs were shipped to Chicago and sold for the Station by the firm of Clay, Robinson & Co., of that place.

Fig. 198.—The Lambs when Starting for Chicago.

Objects Sought in the Experiment.—Prominent among the objects sought in the experiment were the following: 1. To learn the comparative value, in fattening lambs, of certain combinations made up of the chief of the coarse grains grown in the state; 2. To compare feeding such food in limited and unlimited quantities; 3. To ascertain the outcome from feeding such foods to a good type of home grown lambs. The minor objects sought to know: 1. The relative gains that would be secured per month; 2. The relative amounts of food consumed of the various combinations and the gains resulting from them; 3. The relative cost of the gains.

The Animals Used.—The lambs used in the experiment were home grown. They were really good types. In fact they were of a character that would do credit to any grower. One hundred lambs were fed and they were obtained from three sources. The lots from which they were taken numbered 80, 24 and 5 head respectively. The first lot was procured from David M. Fyffe, manager for Hugh Paul, of the Wavertree farm, Dundee, Minnesota. They reached the Station farm on Sept 8, and were kept on pasture with a

supplement of oats until the experiment began. The average weight at the time of purchase was 85 pounds. They cost $4.00 per 100 pounds at Dundee. They were pastured on blue grass of inferior quality until the experiment began Dec. 23, and were also fed a supplement of oats. They consumed 7,501 pounds, hence this food was in a sense their main reliance. Fifteen cents per lamb therefore was deemed an ample charge for the pasture. The price of lambs went away down later in the season and so remained all the winter. They could have been bought two months subsequent to the date of purchase for at least 50 cents less per 100 pounds. They were chiefly high grade Shropshires, but some of the largest specimens were the offspring of a Cotswold cross on high grade Shropshire ewes. In form and quality the lambs of this lot were really good.

The second lot were purchased from Alexander Gunn, of Janesville, Minnesota. They reached the Station on Dec. 17. The average weight at the time of purchase was 99.1 pounds, and the price paid was $3.50 per 100 pounds. In form and breeding they were very similar to the first lot. A few specimens showed indications of Lincoln blood, but the major portion were high grade Shropshires.

The third lot comprised home grown lambs. They were Dorset grades, and were the progeny of a first cross of the pure Dorset on grade ewes. Being late lambs they weighed on an average but 80.6 pounds per head. They were valued at 3½ cents per pound. From the first lot 74 animals were chosen, from the second lot 21. These and the 5 home grown lambs made up the complement of 100 lambs, and they contained both wethers and ewes, but the former were much the more numerous.

Conditions Governing the Experiment.—The 100 lambs were divided into five lots of twenty each. They were fed in compartments of the shed that were side by side. These were 18x20 feet and hinged double doors opened from them northward to yards of a similar size. Except in stormy

weather they had access at will to both apartments, and it is worthy of note that they spent much of the time in the yards. They were provided with water in buckets during the day. Salt was likewise kept before them in boxes. They were weighed singly when put upon experiment, and every week thereafter, and the weights were duly recorded.

Food and Feeding.—The lambs in lot 1 were fed oil-cake, corn and oats, in the proportions of 1, 3 and 6 parts. This food was kept constantly before them after they had been led up to full feed. The lambs in lot 2 were fed the same kinds of grain and in similar proportions, but of this they were only given what they would eat clean. And likewise the lambs in the remaining lots were only given what they would eat with a relish. The lambs in lot 3 were fed oil-cake, barley and oats, in the proportion of 1, 3 and 6 parts. Those in lot 4 were given precisely the same kind of grain food during the first six weeks of the experiment, but during the last five weeks of the same the proportions were changed to 2, 3 and 5 parts respectively of the oil-cake, barley and oats. The lambs in lot 5 were fed oil-cake and oats, in the proportion of 1 and 9 parts, during the first six weeks of the experiment, and in the proportion of 2 and 8 parts during the last five weeks of the same. During the first six weeks of the entire experiment, native hay was fed, and miserable dried stuff it was, owing to cutting too long deferred and also to over-curing. But through the last six weeks of the experiment, hay essentially clover was fed, and of good quality. The oil cake was fed in the pea form. The grain was not ground nor was the hay cut. The aim in feeding was to secure a quick finish, as the lambs were in a good condition of thrift when the experiment began. Some 21 days were occupied in getting the lambs onto full feed.

Estimated Value of the Food.—The food was charged at what were considered the average market values for the same. They were as follows:

Oil Cake, per ton	$14.00
Corn, per bushel of 56 pounds	.18
Barley, per bushel of 48 pounds	.16
Oats, per bushel of 32 pounds	.14
Native Hay, per ton	3.00
Clover Hay, per ton	3.50

Low as these prices are, with the exception of hay, they are nearly the same as the prices for which the various products were actually laid down at the station, and they should certainly demonstrate the great advantage in this respect that the western feeder has and will probably for long years continue to have over the eastern feeder.

Food Consumed.—Table LIV. gives the respective aggregate amounts of grain and hay consumed by the different lots during the experiment proper.

TABLE LIV.—Aggregate Amounts of Food Consumed.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Grain	3821	3710	3645	3655	3695
Hay	900	1459	1355	1361	1286
	4721	5169	5000	5016	4981

The total of grain consumed during the experiment proper was 18,526 pounds, and during the 12 weeks of feeding 19,716 pounds. The total consumption of hay during the first half of the feeding period was 6,311 pounds, and during the last half, 6,780 pounds. And it is also worthy of note that during the first 6 weeks of feeding, while the poor quality of hay was being fed, the consumption of the same was but 2,683 pounds; during the last 6 weeks, while good hay was being fed, the consumption was 4,097 pounds. In other words, the proportion of hay consumed during the first half of the experiment was only 39 per cent. of the whole consumption of hay, and during the last half of the same it was 61 per cent. The bearing of this upon the gains will be referred to later.

Table LV. gives the respective quantities of grain and of hay consumed on an average by one lamb in each group during the experiment proper, and also the sum of these eaten by one lamb.

TABLE LV.—Averages of Food Consumed.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Grain	2.42	2.41	2.37	2.37	2.40
Hay	.58	.95	.88	.88	.80
Totals	3.00	3.36	3.25	3.25	3.20

The average consumption of grain by the lambs in each lot was very uniform, and the same is true of the consumption of hay save with the lambs in lot 1. It will be noticed that with them the consumption of hay was 33⅓ per cent. less than with the lambs of the other lots. The grain, as previously intimated, was fed to them in a self-feeder, and they seemed to make it their chief food. The average daily consumption of grain with the lambs in all the lots was 2.39 pounds, and of hay 1.82 pounds, or a total per day of 3.21 pounds. This consumption of food in proportion to the gains made is small indeed, and speaks much for the high character of the lambs.

Incidents of the Experiment.—On Feb. 20th one lamb died in lot 1, from a digestive trouble. The food was more or less impacted in the stomach, and prompt remedial measures failed to bring relief. This lamb weighed 90½ pounds when put upon experiment, and 104 pounds when he died. Had he lived he would have weighed a little more than 110 pounds at the close of the experiment, on the supposition that the gain made by him subsequently to Feb. 20th had been at the same rate as during the period previous to that time. The value of this lamb is not of course included in the financial summary, nor is any deduction made because of the food consumed by him. But in the reckoning of certain averages, as for instance those which relate to weights

on the whole lot, and on one lamb from 49.2 cents to 22 cents.

When the lambs were ready for sale, the effort was made to sell them to the dealers of St. Paul and Minneapolis, but when informed of the weights of the lambs and the condition of the same, without even inspecting them, as with one voice they said the lambs were too large for their trade. This to the writer was a revelation, as, when feeding lambs in Ontario as late as 1893, the preference was given there to the largest and best finished lambs and so it had been for years previous. As the Chicago buyers also concluded that the lambs were too heavy to bring the topmost price, the change in the market demand in favor of the lamb of but medium weight was thus further emphasized. It is a change that cannot be ignored.

But when the dealers intimated that because of the high finish of the lambs the meat must of necessity be excessively tallowy in character, the writer was sure they were mistaken. The lambs had been fed with a view to the production of the best quality of meat. To test the question, one of the lambs was dressed and served to a company of experts at a leading café in St. Paul. The St. Paul Pioneer Press contained the following in the issue of April 24th, as the verdict of those who feasted upon the lamb: "The mutton was fine and tender, and was probably as delicious a piece of meat as was ever served." The St. Paul Globe, also of the same date, contains the following: "Such sweet, toothsome, succulent lamb never before graced a banquet table in this country." It is unfortunate that the opinion should ever have been cherished by any one that high finish in lambs should of necessity be associated with an undue proportion of tallow.

Weights of the Lambs.—As each individual lamb was given an ear label when the experiment began, and as the weights were recorded every week, it was easily possible to trace the well or ill-doing of the individual lambs, and also

to ascertain their relative progress during different periods of the experiment. A few comments bearing on these features will be given later.

Table LVIII. gives the aggregate weights of the lambs in each lot at the commencement of the feeding period, and at the beginning and close of the experiment proper, with the totals in each instance.

TABLE LVIII.—Aggregate Weights of the Lambs.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Totals
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weights on Dec. 23d, 1895	1,926	1,978	1,921	1,985	1,952	9,762
Weights on Dec. 30th	1,927	1,991	1,937	1,982	1,984	9,821
Weights on March 16th, 1896	2,433	2,617	2,542	2,617	2,587	12,796
Total increase in weight	506	626	605	635	603	2,975

Taking into account the lamb that died, the gains in lot 1 would have been 616 pounds, only 10 pounds less than the gains made by the lambs in lot 2, fed on a similar ration in kind. The cost in making the gain with the former was also a little more than with the latter. On the whole the gains were very uniform.

Table LIX. gives the average weight of the lambs in each lot when the preparatory experiment began, when the experiment proper began and closed, and the average total increase made by the lambs in each lot.

TABLE LIX.—Average Weights and Average Gains.

	On Dec. 23, 1895.	On Dec. 30, 1895.	On March 16, 1896.	Average Increase.
	Lbs.	Lbs.	Lbs.	Lbs.
Lot 1	96.8	96.4	128.0	31.6
Lot 2	98.9	99.6	130.9	31.3
Lot 3	96.5	96.9	127.1	30.2
Lot 4	99.3	99.1	130.9	31.8
Lot 5	97.6	99.2	129.4	30.2
Averages	97.7	98.2	129.2	31.0

A number of the lambs exceeded 150 pounds in weight. The heaviest lamb weighed 170 pounds when the experiment closed. Taking the dead lamb into the account will

reduce the average increase in Lot 1 to 30.8 pounds, as only 19 lambs are accounted for in the above table when the said increase is found. The average monthly gains made by the lambs of the respective lots, counting in the lamb that died, were as follows:

	Pounds.
Lot 1	12.0
Lot 2	12.2
Lot 3	11.8
Lot 4	12.4
Lot 5	11.8
Average	12.0

These gains, in proportion to the food fed, are unusually good, and they tend to show, first, the marked capacity of well-grown Minnesota lambs to make growth; and, second, the marked suitability of the foods used for making growth in our winter climate. The writer never succeeded in obtaining gains so good when feeding lambs in Ontario on a diet of clover hay, oats, peas and field roots, and

Fig. 199.—Five of the Lambs. Average Weight 155 Pounds.

when it is borne in mind that these foods are all staples on the farms of our state, the possibilities in feeding sheep and lambs in the same would seem to be very great. Some of the individual gains made were extraordinary. One lamb went into the experiment at 96 pounds and came out of it 84 days later at 151 pounds. It thus gained 55 pounds, or .655 pounds per day. The smallest gain made was 8 pounds. It should also be noticed that while during the first six weeks of the experiment the total gains were 1,453 pounds, during the last six weeks they were 1,691 pounds, or 238 pounds more, a very unusual experience in feeding, and doubtless attributable to the good hay fed during the last half of the feeding period.

Increase in Value.—Table LX. gives the value of the food fed during the experiment proper, the value of the increase in weight made by the lambs of the respective lots and the profit on the said increase in weight.

TABLE LX.—Increase in Value During the Experiment Proper.

	Value of Food Fed	Value of Incease in Weight	Profit on Increased Weight
Lot 1	$18.83	$25.27	$6.44
Lot 2	18.33	26.54	8.21
Lot 3	18.03	25.65	7.62
Lot 4	18.55	26.92	8.37
Lot 5	19.86	25.57	5.71
Totals	$93.60	$129.95	$36.35

In the above computation the increase in weight is valued at $4.24 per 100 pounds, the net price received for the lambs in Chicago. The estimated gain made by the lamb that died, which is put at 20 pounds, is not included in the reckoning. In every instance, therefore, a substantial profit was made on the increased weight during the experiment. The ability to make such gain gives the western feeder a great advantage over the eastern feeder, and this advantage arises, of course, from the greater cheapness of foods in the east. If the lambs could have been sold at the ordinary prices obtainable for such animals in an ordinary

year, the profit made from feeding them would have been a most handsome one.

The average cost of making 100 pounds of increase in weight during the experiment proper, without the gains made by the dead lamb, was $3.05. The cost of making 100 pounds of increase with the lambs in lot four, which were given more oil-cake that those in lot three, was $2.92. Cheaper gains have doubtless been made in Minnesota from feeding screenings at from $3.00 to $5.00 per ton, but gains so cheap were never made by the writer before when fattening sheep and lambs, and may never be made again, at least in this state. With the increase of live stock production which is sure to come the price of food must rise. The growers of live stock are the truest friends therefore of the farmers who are engaged in growing grain only. The cost of making 100 pounds of increase with the lambs in lot four was $3.29, or 37 cents per 100 pounds less than with the lambs in lot five; hence the importance of looking well to the relative cost of foods when determining upon them for feeding.

Financial Statement.—Value of 99 lambs on March 17, 1896, on the basis of shrunk weights and of the net price received for those shipped to Chicago.....		$515.41
Value of 100 lambs on Dec. 30, when the experiment proper began, on the basis of cost.....	$399.72	
Cost of food.....	93.60	
Total cost.....		493.32
Total net profit.....		$22.09
Total net profit on one lamb.....		.22

Observations.—1. In the above statement the value of the lamb that died is not of course included, and the cost of the food fed to it is also charged against the experiment.

2. The food fed is charged at the average market values paid for the same. To charge it at home values, the true basis of valuing such foods fed upon the farm, should still further lessen the price put upon it.

3. Even at the low price for which the lambs were sold, they would have averaged to the grower, shrunk weight, $5.91 per head.

IMPORTANT FACTS SUMMARIZED.

Values—

1.	Average value per 100 pounds on the basis of cost when the experiment began, Dec. 23th, 1895	$4.04
2.	Value per 100 pounds when the experiment proper began, Dec. 30th, 1895	4.07
3.	Value per 100 pounds on the basis of shrunk weights when delivered in Chicago, March 18th, 1896	4.65
4.	Estimated value per 100 pounds on the basis of actual receipts after deducting the expense incurred in the shipment and sale of the lambs	4.24
5.	Difference per 100 pounds between the cost price when the feeding began and the selling price in Chicago	.61
6.	Difference per 100 pounds between the cost price when the experiment began and the selling price in Chicago, after deducting the expense of marketing	.20

Freights—

1.	Cost of freight per lamb on each of the 80 lambs brought from Dundee, Minn	.18
2.	Cost of freight per lamb on each of the 24 lambs brought from Janesville, Minn	.15
3.	Cost of freight per lamb on each of the 84 lambs shipped to Chicago when marketed	.41
4.	Cost of freight on a single deck car from the Minnesota transfer to Chicago	34.40

Weights—

	Lbs.
1. Average weight per lamb of 80 lambs shipped from Dundee to the Station	85.
2. Average weight per lamb of 24 lambs shipped from Janesville to the Station	99.1
3. Average weight per lamb of the 5 home-bred lambs when put into the experiment	86.6
4. Average weight of 100 lambs used in the experiment when the feeding began, Dec. 23th, 1895	97.7
5. Average weight when the experiment proper began, Dec. 30th, 1895	98.2
6. Average weight at the close of the experiment, without shrink, March 16th, 1896	129.2
7. Average weight at the close of the experiment, with a shrink of 5 per cent	122.8

Increase in Weight—

1. Average increase in weight made by each lamb during the experiment proper (77 days)	31.0
2. Average increase per month during the experiment proper	12.0

Food Consumed—

1. Average amount of grain consumed per day by each lamb during the experiment proper	2.39
2. Average amount of hay consumed per day by each lamb during the experiment proper	.82
3. Average amount of food consumed per day by each lamb during the experiment proper	3.21

Cost of Increase—

1. Cost of making 100 pounds of increase in weight during the experiment proper	$3.05
2. Cost of making 100 pounds of increase with the lambs in lot 4, which were fed a larger proportion of oil cake	2.92

Profits—

1.	Average value of each of the 100 lambs put into the preparatory experiment Dec. 23d, 1895	$3.94
2.	Average value of each of the 100 lambs put into the experiment proper, Dec. 30th, 1895	4.00
3.	Average value of each lamb (99) at the close of the experiment, March 16th, 1895, without shrink	6.01
4.	Average value of each lamb (99) at the close of the experiment with a shrink of 5 per cent	5.91
5.	Average advance in value over the cost made by each lamb during the entire feeding period	3.07
6.	Total net profit from feeding 100 lambs for 84 days, the entire period of feeding	22.09
	Total profit on one lamb without shrink	.47
7.	Total net profit on one lamb	.22

CONCLUSIONS.

The following are among the more important of the conclusions that may be gleaned from this experiment:

1. That all the food combinations used in the feeding proved very suitable for fattening lambs.

2. That of these combinations, barley and oats, with oil meal added in larger quantity, produced the largest increase in weight and at the least cost.

3. That although a combination of oil cake and oats produced fair gains, it was the most costly grain food fed.

4. That the greater consumption of good clover hay as compared with inferior native hay, and the greater gains resulting, emphasizes the importance of feeding good fodder.

5. That the average gains made by the lambs, viz., 12 pounds per month, were extraordinary from the food fed, viz., 3.21 pounds per day.

6. That the low price of western foods makes it possible to produce mutton very cheaply, since in this experi-

ment with the lambs in lot 4, 100 pounds of increase was made at a cost of but $2.92.

7. That feeding lambs on an unlimited grain ration as in this experiment is not so satisfactory as feeding them on the same in quantity adapted to their daily needs.

8. That very large lambs are not the best adapted to the changed market conditions.

FATTENING RANGE LAMBS.

SECTION NO. 2.

THOS. SHAW.

Sheep and lambs are grown every year upon the vast ranges that lie westward from Minnesota, and in numbers that run up into the millions, and so it is likely to be in all the years that are yet to come. The grazing of cattle upon the western ranges may possibly decrease, but the growing of sheep, from the very nature of things, is likely to increase. In a long succession of train loads, every year, these sheep and lambs pass through our state, while being sent to the feed lot on the market. With the exception of what is being done at the stock yards of South St. Paul and New Brighton, fattening sheep and lambs has received almost no attention at the hands of the Minnesota farmer. This experiment, therefore, was undertaken to ascertain whether a good profit could not be made by the farmers of the state from feeding range lambs.

It would, doubtless, be correct to say that the major portion of the sheep fattened west of Chicago are fattened at stock yards established at various feeding centers along the lines of railway. They are fattened at these in a wholesale way, which is oftentimes, in the very nature of things, attended with a high mortality. The food fed to them must all come from the farm, and the regretable feature about it is, that the wheat screenings which forms the principal portion of the food is all given away by the farmers, and a large portion of the manure made is utterly wasted. This experiment was undertaken, therefore, in the hope of doing something that would tend to divert this industry to its rightful channel, that is to say, from the stock yards to the farm. It is even now a great industry, but there are good

reasons for believing that it is only in its infancy. It is exceedingly to be desired, therefore, that the Minnesota farmer should participate in the benefits thereof, providing he finds profit in it. And to encourage him in the work all the railroad lines running over the northern half of the state will allow of feeding in transit. This means that the intending feeder may purchase feeding stocks to the westward. He can then pay the freight on them to the point of ultimate delivery, can unload them at his nearest station on the way, can feed them there for a season, and can then re-ship them with no further charge than a nominal sum for shunting the car.

Time Covered by the Experiment.—The lambs were put on food Nov. 10, 1896, and the preparatory feeding then begun continued for six days. The experiment proper began Nov. 16, and ended Feb. 8, 1897. It thus covered a period of 12 weeks or 84 days. They were still kept on full feed until March 24 following, when they were sent to the block. The lambs were fed in all, therefore, for 134 days.

Objects Sought in the Experiment.—Chief among the objects of the experiment were the following: To ascertain, 1. The suitability of range lambs for being fattened under what may be termed farm conditions; 2. The relative adaption of various foods for fattening lambs, such as are easily accessable to the farmer; 3. The probable outcome viewed from the standpoint of profit. The secondary objects sought information bearing upon such points as, 1. The consumption of food; 2. The gains per month; 3. The cost of making 100 pounds of gain; 4. The duration of the fattening period that would show the greatest profit.

The Animals Used.—The lambs used in the experiment numbered 120. They were taken from a lot of 160 shipped down from Crookston on October 28. They formed part of a carload of lambs and wethers that had been purchased by the writer in the range country in Montana late in September. They were bought on Prospect Ranch, of which

Wm. B. Shaw is the manager, and were shipped in a double deck car from Culbertson, 702 miles west from St. Paul. There was one deckload of lambs and one of wethers. The former numbered 187, and the latter numbered 100.

Col. W. M. Liggett, the director, was anxious to ascertain the outcome from pasturing the whole lot for a time at the sub-experiment station farm at Crookston, as native pasture at the time was plentiful there. They were accordingly unloaded at that station. That part of the experiment was not satisfactory. The weather turned cold and stormy that autumn at a period unusually early. The severe frosts killed the native pasture, and in the absence of suitable protection the lambs did not make that progress that had been anticipated. Not a few of them had contracted colds in the meantime, which no doubt hindered to some extent their future well-doing.

The lambs were chosen for the experiment on the ground of uniformity rather than on that of absolute size. They were the offspring of grade Merino dams and Oxford Down sires. Nearly all of them had the dark face and legs of the

Fig. 200.—The Lambs on Reaching Crookston.

Oxford Down, while some of them still retained the flattish rib and traces of the wrinkly neck which speak of Merino blood. They were late lambs, as Montana lambs must of necessity be. They were dropped in May. They weighed on an average but 43.8 pounds per head when they reached Crookston, but these weights were taken soon after they left the car and when they were greatly shrunken from prolonged fasting. The lambs selected for feeding weighed on an average 57.2 pounds without shrink when put into the experiment.

The whole lot cost on an average $1.25 per head in Montana. On the basis of the shrunk weights at Crookston, this would make the price $2.85 per 100 pounds, and on the basis of unshrunk weights, allowing the average weight to be 48 pounds before shipment, it would fix the price at $2.60 per 100 pounds. As the lambs which were put under experiment were somewhat better than the average, it will be equitable to charge them at $2.85 per 100 pounds; that is to say, a virtual advance of 25 cents per 100 pounds over the price paid in Montana. This would make the average cost of each lamb $1.93, or $3.37 per hundred when the preparatory experiment began, as will be shown below.

Conditions Governing the Experiment.—The lambs were divided into four lots, with 30 lambs in each lot. They were divided as evenly as possible, on the basis of general form and aggregate weights. They were fed in the apartments of a shed, 18x20 feet being allowed to each lot. These apartments were side by side, and each opened by double-hinged doors into yards of similar size. The yards are on the north side of the building, which of course was not favorable to the experiment. They were kept nicely littered, and the lambs had access to them at will day and night, except in stormy weather. Water kept in buckets was virtually accessible at all times during the day, and common salt was kept in small boxes in each apartment of the shed.

The lambs were weighed singly at the beginning of the experiment, and every week thereafter, and a most careful record was kept of the weights.

Food and Feeding.—The grain portion given to the lambs was as follows: Those in lot 1 were fed oil cake, wheat bran, corn and oats in the proportions of 1, 2, 3 and 4 parts respectively by weight. The lambs in lot 2 were fed oil cake, bran, barley and oats in similar proportions. In lot 3 they were fed bran, oil cake, barley and oats in the proportions of 1, 2, 3 and 4 parts. With the lambs in lot 3, therefore, the quantities of bran and oil cake fed respectively were reversed as compared with those of lot 2. And in lot 4 they were fed oil cake and oats in the proportions of 1 and 9 parts. The fodder consisted of native hay only. The experiment therefore was virtually a test between corn, barley and oats as food factors in fattening lambs.

The quality of the food was excellent, except the hay, which was very poor. It had been cut from native prairie meadow, unharvested the previous year, and much of it therefore was simply dead grass, alike unpalatable and unnutritious. This accounts for the small relative consumption of hay, and in part at least for the very moderate gains made by the lambs.

The oil cake was fed in the pea form. The grain was not ground nor was the hay cut. The lambs were given of both grain and hay what they would eat clean with a relish. If any indication of loathing of food was noticed, the quantity of food was reduced. They were gradually led up to a full ration. The time thus occupied was about 21 days.

Estimated Value of the Food.—The food was charged at what were considered average market values in the state as nearly as these could be ascertained. The prices affixed to the various factors of the ration on the above basis were as follows.

Oil Cake, per ton	$14.00
Bran, per ton	6.50
Corn, per bushel of 56 pounds	.18
Barley, per bushel of 48 pounds	.16
Oats, per bushel of 32 pounds	.14
Hay, per ton	3.00

The prices actually paid for the oil cake, corn, barley and oats were virtually about the same as those given in the estimate, and the bran, which is charged at $6.50 per ton, only cost $4.50 at the Minneapolis mills. These figures represent unusually low prices, lower probably than will ever be seen again in the Northwest. The revival in meat production which was manifest while this experiment was being conducted means also an increase in the prices of grain.

Food Consumed During the Experiment Proper.—Table LXI. gives the quantity of food consumed by the lambs in each lot during the experiment proper.

TABLE LXI.—Food Consumed.

	Lot 1	Lot 2	Lot 3	Lot 4	Totals
	lbs.	lbs.	lbs.	lbs.	lbs.
Grain	5,127	4,974	5,127	4,771	19,999
Hay	1,208	1,200	1,196	902	4,506
Totals	6,935	6,174	6,323	5,673	24,505

The lambs in lot 4 were considerably the lowest in consumption of food and next to them in this respect were the lambs in lot 2. They were also the lowest in increase in weight as will be shown below, although the lambs in lot 4 were slightly ahead of those in lot 2 in gains made. In this we have another evidence of the relation between a free consumption of food and good gains, and vice versa. The consumption of fodder was scarcely 23 per cent of the consumption of grain, a proportion that would seem to be too small to produce the best returns, but it was occasioned by the poor quality of the hay.

Table LXII. gives the averages of food consumed per day by the lambs of each lot, and by those in all the lots during the experiment proper.

TABLE LXII.—Food Consumed by Each Lamb.

	Lot 1	Lot 2	Lot 3	Lot 4	All the lots
	lbs.	lbs.	lbs.	lbs.	lbs.
Grain	2.03	1.97	2.03	1.89	1.98
Hay	.48	.48	.47	.36	.45
Totals	2.51	2.45	2.50	2.25	2.43

The total consumption of food was relatively low, even for light lambs, but it was occasioned as heretofore stated by the poor quality of the hay. Those who feed a poor quality of fodder purposely, as is sometimes done, to force a greater consumption of grain, are in error. Grain and fodder must be fed in equilibrium to obtain the very best results. To ascertain this equilibrium presents a wide field for investigation. It will be observed that the lambs in lot 3 consumed quite a little more food than those in lot 2. This probably arose from the favorable influence which the larger quantity of oil-cake fed to them exercised on digestion, as this was the only difference in the ration fed to the lambs of these respective lots.

Value of Food Consumed.—Table LXIII. gives the respective values of the food consumed during the preparatory experiment and the experiment proper, and the total cost of the same.

TABLE LXIII.—Value of Food Consumed.

	Preparatory Experiment	Experiment Proper	Totals
Lot 1	$1.29	$22.64	$23.93
Lot 2	1.30	22.18	23.48
Lot 3	1.39	24.74	26.13
Lot 4	1.44	23.90	25.34
Totals	$5.42	$93.46	$98.88

The lambs in lot 3 cost the most for food and yet they made the largest profit as will be shown below. Those in lot 4, which came second in point of cost, are lowest in point of profit. They are so placed by the relative higher price of the oats fed rather than by the lesser gains made.

Profits Made During the Experiment Proper.—Table LXIV. gives the value of the lambs in each lot: 1. At the commencement of the experiment proper; 2. The cost of food fed during the same; 3. The total cost of the lambs up to the close of the experiment proper; 4. The value of the lambs at that time; 5. The profit made on the lambs in each lot during the experiment.

TABLE LXIV.—Profits Made During the Experiment Proper.

	Lot 1	Lot 2	Lot 3	Lot 4	Totals
Value Nov. 16th, 1896.....	$59.96	$58.82	$58.79	$59.10	$236.67
Cost of Feed.....	22.64	22.18	24.74	23.90	93.46
Total Cost.....	$82 60	$81.00	$83.53	$83.00	$330.13
Value on Feb. 8th, 1897.....	112.76	110.37	116.51	111.35	450.99
Profit.....	$30.16	$29.37	$32.98	$28.35	$120.86

The profit thus made on each lamb from feeding it for 77 days, was $1.01. This profit is based upon the actual cost of the lambs when the experiment proper began, the cost of the food fed deducted from the sum produced reckoning the lambs at the same rate as they were actually sold for on March 24th, but it does not include any shrink. The statement with shrunk weight included is made later. They were bought by E. M. Prouty & Co., South St. Paul, for W. E. McCormick, also of St. Paul, to be sold by the latter in the dressed form to retailers. The price paid was $4.87½ per 100 pounds, live weight. The average cost of each lamb was $1.93 when the preparatory experiment began and the value per 100 pounds was $3.37. These figures were obtained as now described: The lambs in Montana cost on an average $1.25 each. This on the basis of greatly shrunken weight, taken at Crookston, viz., 43.6 pounds per

lamb, made the price per hundred in Montana $2.85 on the basis of unshrunk weight. Averaging the lambs at 48 pounds each, it would make the price per hundred in Montana $2.60. But, as previously stated, the lambs on going into the experiment were charged at $2.85 per hundred, as they were considered a little better than the average of the whole lot. The value of each lamb, therefore, put under experiment, was $1.63 in Montana, as they weighed 57.2 pounds on an average. The average of freight on each lamb on the basis of weights was 19.1 cents; and the average freight for each lamb going into the experiment on the same basis was 23 cents; and 7 cents per lamb was allowed for pasture. Adding $1.63, therefore, the cost per lamb in Montana, 23 cents, the cost of freight, and 7 cents, the cost of pasture, gives $1.93 as the cost per lamb on Nov. 10th, and $3.37 as the cost per hundred. When the experiment proper began, however, the cost had been increased to $1.97 per lamb and to $3.44 per hundred. These are higher prices, relatively, than were paid for the average of such lambs in the stockyards at the time.

Weights of the Lambs.—Table LXV. gives the aggregate weights of the lambs in each lot when the preparatory feeding began, and when the experiment proper began and closed, with the total weights and the aggregate increase in weight during the experiment proper.

TABLE LXV.—Weights of the Lambs.

	Lot 1	Lot 2	Lot 3	Lot 4	Totals
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight on Nov. 10th, 1896	1,705	1,725	1,685	1,745	6,860
Weight on Nov. 16th, 1896	1,743	1,710	1,709	1,718	6,880
Weight on Feb. 28th, 1897	2,313	2,264	2,390	2,284	9,251
Total increase in weight	570	554	681	566	2,371

It will be noticed that during the preparatory period the 120 lambs made a total increase of only 20 pounds. The bad condition in which they reached the station seemed to tell against them during the entire experiment.

Table LXVI. gives the average weight of the lambs in each group when the feeding period began, and when the experiment proper began and closed, with the average of increase made by one lamb in each group, and also the aggregate of increase made by the lambs in the respective lots.

TABLE LXVI.—Average Weights.

	On Nov. 10th, 1896.	On Nov. 16th, 1896.	On Feb. 8th, 1897.	Average Increase.	Aggregate Increase.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot 1.	56.8	58.1	77.1	19.0	570
Lot 2.....	57.5	57.0	75.5	18.5	554
Lot 3.....	56.2	57.0	79.7	22.7	681
Lot 4.....	58.2	57.2	76.1	18.9	566
Averages..	57.2	57.3	79.1	19.8	593

It will be noticed that the lambs in lot 3 made an aggregate increase of 84 pounds more than the lambs in lot 1, which came second in the gains made. They also made an aggregate gain of 127 pounds more than the lambs in lot 2, which were fed similarly except that those in lot 3 were given a double portion of oil cake.

The average increase per month during the experiment proper of the lambs of the respective lots was as follows:

	Lbs.
Lot 1	6.78
Lot 2	6.60
Lot 3	8.11
Lot 4	6.74
Average	7.06

These gains are not high in any instance; in fact, they are relatively low, except with the lambs in lot 3. The reasons are doubtless found in the somewhat shaky condition of the lambs when put under experiment, and in the inferior character of the hay fed.

Profit on the Increase Made During the Experiment Proper.—Table LXVII. gives the value of the increase made by the lambs of each lot during the experiment proper, the cost of making the same, and the profit on the said increase.

TABLE LXVII.—Profit on Increase.

	Value of Increase.	Cost of Increase.	Profit on Increase.
Lot 1	$27.79	$22.64	$5.15
Lot 2	27.01	22.18	4.83
Lot 3	33.20	24.74	8.46
Lot 4	27.59	23.90	3.69
Totals	$115.59	$93.46	$22.13

It will be noticed that in every instance a profit was made on the increase in weight during the experiment proper. When this can be done, substantial profits are assured under ordinary conditions. This profit arose not so much from the good gains made as from the low cost of the food. Much the largest profit was made on the lambs in lot 3, which were given the double portion of oil cake. The least profit was made on the lambs in lot 4, not because of low gains made, but rather on account of the higher relative prices of the grain portion fed to them. The average cost of making 100 pounds of increase during the experiment proper was $3.94, while the price obtained for the lambs on March 24th was $4.87½. The lambs were quite ready for the market when the experiment proper closed, and the selling price therefore should be put as high as when the lambs were sold.

Financial Statement.—Value of the lambs on Feb. 28th, 1897, at $4.87½ per 100 pounds, and with a shrink of 4 per cent, $432.95

Value of the lambs when the experiment began, Nov. 16th, on the basis of cost.....$236.57

Cost of food fed..... 93.46

Total Cost..... 330.13

Total profit..... $102.82

Net profit on each lamb..... 1.06

Observations.—The value of the manure is supposed to offset the items of bedding, labor and interest on the invest-

ment. Whether this estimate is too favorable to the experiment, as applied to average farm conditions, must be determined by each farmer for himself.

2. If the food had been charged at home values the profit would be increased, as the home value of food is always less than the market value.

Disposal of the Lambs.—It would be impossible to give a statement bearing upon the disposal of the lambs that would be complete in every detail. On Feb. 28, when the experiment proper closed, the lambs were in a good condition of finish and then it was that they should have been sold. But the sale was delayed to find a home market for them rather than ship them. This resulted in a delay which kept them in the feeding pens until March 24. In the meantime a limited number of them were slaughtered for use in the supply department of the school of agriculture. Five lambs died in the interval between Feb. 28 and March 24. They seemed to be affected similarly, that is to say, the urinary organs were affected. In nearly all instances the bladder was more or less inflamed, and the kidneys were sympathetically affected. The trouble was supposed to originate in the somewhat shaky condition of the lambs induced by autumn exposure, prior to the feeding period, which so weakened the constitution as to unfit them for prolonged heavy feeding. These losses would of course detract from the profits during the entire period of feeding, and their occurrence emphasizes the great importance of promptly disposing of animals when ready for the block. Another lamb was also lost in the autumn, making six in all. It was affected with tapeworm. The entire loss, therefore, was 2.4 per cent as 245 lambs and wethers in all were brought to the station from Crookston, and in nearly all instances the animals lost were relatively low in value. With the exceptions named, the lambs were sold as previously stated.

IMPORTANT FACTS SUMMARIZED.

Values.—

1.	Price paid per 100 pounds for the 187 lambs bought in Montana on the basis of unshrunk weights	$2.60
2.	Price charged per 100 pounds in Montana against the 120 lambs put into the experiment	2.85
3.	Price per 100 pounds on the basis of cost for 120 lambs put under experiment Nov. 16, 1896	3.44
4.	Value per 100 pounds on Feb. 28, 1897, when experiment proper closed, based on the price for which the lambs were sold March 24	4.87½
5.	Difference per 100 pounds between cost price and selling price	1.43½

Freights.—

1.	Cost of freight per lamb on 187 lambs brought from Montana, on the basis of weights	.19
2.	Cost of freight per lamb on 120 lambs put into the experiment, on the basis of weights	.23
3.	Cost of freight per wether on 100 wethers of same shipment, also computed on the basis of weights	.43½
4.	Cost of freight on one car carrying 187 lambs and 100 wethers from Culbertson to St. Paul, 702 miles, with $1.40 added as cost of food	79.40

Weights.—

		Lbs.
1.	Average weight per lamb of the entire shipment on reaching Crookston	43.8
2.	Average weight of the same in Montana. Estimated	48.0
3.	Average weight per lamb of the 120 lambs put into the experiment Nov, 10, 1896	57.2
4.	Average weight per lamb when the experiment proper began, Nov. 16	57.3
5.	Average weight per lamb when the experiment proper closed, Feb. 28, 1897	91.1

Increase in Weight.

	Lbs.
1. Average increase in weight made by each lamb during the 77 days of the experiment proper.....	18.9
2. Average increase per month during the experiment proper.....	7.06
3. Average increase per month of lot three, fed a double portion of oil-cake.....	8.11

Food Consumed.—

1. Average amount of grain consumed per day, per lamb, during the experiment proper.....	1.98
2. Average amount of hay consumed per day, per lamb.....	.45
3. Average amount of hay and grain consumed per day, per lamb.....	2.43

Cost of Increase.—

1. Average cost of making 100 pounds of increase during the experiment proper.....	3.94
2. Cost of making 100 pounds of increase with the lambs in lot 3.....	3.63

Profits.—

1. Average value of each lamb put into the experiment when bought in Montana.....	1.63
2. Average value of each lamb at the beginning of the preparatory experiment, Nov. 10, 1896.....	1.93
3. Average value of each lamb at the beginning of the experiment proper.....	1.97
4. Average value of each lamb at the close of the experiment proper, shrunk weight.....	3.61
5. Average increase in value from 77 days' feeding..	1.64
6. Average profit per lamb during the experiment proper, shrunk weights not considered.....	1.01
7. Average profit per lamb on the basis of shrunk weights.....	.86

CONCLUSIONS.

The following are chief among the conclusions to be drawn from the experiment:

1. That the various grain food factors used in the experiment are well adapted for feeding lambs, though not equally so.

2. That of all the grain factors used, a mixture of bran, oil-cake, barley and oats, fed in the proportions of 1, 2, 3 and 4 parts respectively, make a particularly excellent ration for lambs.

3. That oats and oil-cake, when fed as in this experiment, produce good gains relatively, but when so fed a due regard must be had to their cost.

4. That when lambs are ready for the market it is well to market them promptly.

5. That range lambs are well adapted to the purposes of the Minnesota feeder.

6. That under the conditions of the experiment, lambs bought upon the ranges can be more than doubled in value when fed for a reasonable period.

FATTENING RANGE LAMBS.

SECTION NO. 3.

THOS. SHAW.

This experiment was conducted on lines very similar to those which characterized the experiment of the previous winter. The chief points of difference relate to some changes in the foods fed, which will be duly noted below. The great rise in values which characterized all grades of sheep during the year 1897 more than justified the attention given to this branch of the live stock industry at the station.

Time Covered by the Experiment.—The preparatory experiment began Nov. 1st, 1897. The experiment proper began 7 days later, that is to say, on Nov. 8th, and ended on Feb. 28th, 1898, thus covering a period of 16 weeks, or 112 days. But the lambs were continued on full feed until March 12th, the date of delivery for slaughter. The whole feeding period, therefore, covered a period of 131½ days.

Objects Sought in the Experiment.—Among the primary objects of the experiment were the following: 1. To ascertain the suitability of range lambs for being fed under what may be termed ordinary farm conditions. 2. To ascertain the relative adaptation in feeding lambs on certain combinations of grain foods such as are easily accessible to the farmer; and, 3, to ascertain the profit, if any, from feeding range lambs under what may be termed ordinary Minnesota conditions.

The secondary objects sought to learn: 1. The relative resulting increase in weight from feeding the foods used in the experiment; 2. The relative cost of one pound of increase in weight received; and, 3, the probable duration of the period during which lambs may be fed profitably on

such foods. In brief, the experiment sought to confirm the results obtained the preceding winter from feeding range lambs.

The Animals Used.—One hundred and twenty lambs were fed. They were purchased by the Hon. W. M. Liggett, the Director of the station, and the writer, from Wm. B. Shaw, manager of Prospect Ranch, Culbertson, Montana. In all 300 lambs and 25 wethers were bought. They were all brought over the Great Northern Railroad in a double-deck car to the Minnesota Transfer, and at the ordinary rates for freight. They reached the station on October 20th, and were kept on blue grass pasture, plentiful but dry in character, until the preparatory experiment began, 10 days later. They were grade lambs, and were evidently possessed of various blood elements. Prominent among these were the indications of Merino and Oxford Down blood. The former of these was evidently the dominant foundation element, though but few traces of wrinkles were

Fig. 201.—The Lambs in Lot 1 when nearly finished.

visible in the lambs. The sires were unregistered Oxford Down rams, but evidently pure in breeding. The dark face and legs had been engrafted on nearly all of the lambs.

In choosing the lambs for the experiment, uniformity in size and shape was sought rather than size alone. While the average weight of the whole lot when they reached the farm was 55½ pounds, those put into the experiment averaged 60.4 pounds at its commencement, 10 days later. As from want of shed room all the lambs could not be accommodated at the farm, 100 of them were sold to Joseph Carroll, of Rosemount, in our state. The price paid was $2.10 per head, and the average weight was about 59 pounds. Mr. Carroll fed these lambs at his farm, and made a nice profit on them. The balance of the lambs purchased were fed, nearly all of them, under experiment. The particulars of this experiment will be given in a subsequent bulletin.

The wethers, or at least 20 of them, were fed under conditions similar to those which were observed in feeding the lambs in lot 1, as described below. The particulars which relate to the feeding of these wethers, and the actual and comparative outcome of the same, will be given in a subsequent bulletin.

Conditions Governing the Experiment.—The lambs were divided into four lots, with 30 in each lot. That they were very evenly divided will be apparent from the respective weights of each lot given below. The lambs in each lot occupied separate apartments in the shed. These were side by side, and on the north side of the building, which was probably somewhat against the experiment. Each compartment was in size, 18x20 feet, and each opened by means of a double-hinged door into an open yard of similar dimensions. They had access at will to the yards, except in stormy and windy weather. The sheds and yards were kept nicely bedded. The lambs were all wethers, hence the conditions of the experiment were very even.

Each lamb was weighed singly at the commencement of

the preparatory experiment, at the beginning of the experiment proper, and every 14 days subsequently until sent to the block. They had access to water virtually at will, which was given to them in pails. Common salt was also kept accessible to them at all times.

Food and Feeding.—The grain portion fed to the lambs in the respective lots was as follows: In lot 1 they were given oil cake, wheat bran and oats, in the proportions of 1, 2, 3 and 4 parts respectively, by weight. In lot 2, oil cake, bran, barley and oats, in similar proportions. In lot 3 they were given bran, oats and barley in the proportions of 3, 3 and 4 parts; and in lot 4, oil cake, bran and oats, in the proportions of 1, 2 and 7 parts. The fodder given was mixed hay, clover predominating in the mixture, and sorghum ensilage. The ensilage was made from sorghum grown thickly and cut when approaching the mature stage. The sorghum was not fed until December 28th, and it was continued until the lambs were sold.

As the fodder fed to each lot was the same in kind, the experiment sought to ascertain the respective values of corn with oil cake, barley with and without oil cake, and oats with the same, for fattening lambs. The grain was fed unground, and the oil cake was given in the "pea" form. The lambs were led up gradually to a full ration, and were virtually given all of each kind of food that they would eat with a relish. The hay was fed uncut. The grain and hay were fed in two feeds, morning and evening, and the ensilage was given in the evening only.

Estimated Value of the Food.—The food was charged at the average market values in the state, when delivered at the place of sale. Though these values were based on careful estimates, they are to be regarded only as close approximations. They fixed the prices of the respective kinds of food used as follows:

Oil Cake, per ton	$22.00
Wheat Bran, per ton	7.50
Corn, per bushel of 56 pounds	.22
Barley, per bushel of 48 pounds	.20
Oats, per bushel of 32 pounds	.17
Mixed Hay, Clover and Timothy, per ton	4.00
Sorghum Ensilage, per ton	1.20

With some of the food products these values were less than the prices actually paid at the station. Corn, for instance, which was charged at 22 cents per bushel, actually cost the station 25½ cents. In other instances the price charged was in excess of the price paid. Bran, which was charged at $7.50 per ton, actually cost the station but $4.50 per ton. It had been bought some time previously, but the necessity for using average prices for the state will be apparent.

Food Consumed.—Table LXVIII. gives the respective amounts of grain, hay and sorghum ensilage consumed by the lambs during the 112 days of the experiment proper.

TABLE LXVIII.—Food Consumed During the Experiment.

	Lot 1	Lot 2	Lot 3	Lot 4
	Lbs.	Lbs.	Lbs.	Lbs.
Grain	6,330	6,256	6,005	6,252
Hay	2,771	2,773	2,735	2,635
Ensilage	1,024	1,026	1,034	6,252
Totals	10,125	10,055	9,774	9,933

The lambs in lot 3 consumed considerably less grain than those in the other lots, and it will be noticed that the gains were correspondingly low. When barley is an important factor in the grain fed, it would seem to be decidedly advantageous to feed more or less oil cake along with it. This conclusion is based upon the behavior of the lambs in lots 2 and 3, the latter of whom did not receive any oil cake until near the close of the experiment. A small amount of oil cake added to the mixture would seem to have a stimulating effect on the appetite.

Throughout the experiment proper each lamb consumed daily on an average the following amounts of the respective kinds of food:

	Pounds.
Grain	1.85
Hay	.81
Ensilage	.45
Total	3.11

Incidents of the Experiment.—On the night of January 25th, or 78 days after the commencement of this experiment, one of the best lambs in lot 2 got "cast," that is to say, it rolled on its back, and being unable to recover its natural position, it died. This circumstance to some extent proves a disturbing factor in nearly all the computations which relate to the experiment. Apart from this, the experiment was remarkably free from unusual accidents of any kind. The health of the lambs was good throughout, and the gains were also fairly uniform. One hundred and five days after the beginning of the experiment proper, about 10 per cent. of oil cake was added to the grain portion given to the lambs in lot 3, and 7 days later this proportion was further increased. But during the succeeding interval of 26 days which elapsed before the lambs were sent to the block, the only perceptible influence of the oil cake was an improvement in the appetite. Near the middle of the experiment, the oil cake given to the lambs in lot 4 was increased from one to two tenths of the grain fed, and the bran was correspondingly decreased. This change was designed from the first, but the only perceptible result that followed was some little improvement in the appetite of the lambs.

Value of Food Consumed.—Table LXIX. gives the respective values of the food consumed during the preparatory experiment, the experiment proper, and the period intervening between the close of the experiment and the sale of the lambs, and also the total cost of the food consumed.

TABLE LXIX.—Values of Food Consumed.

	Preparatory Experiment.	Experiment Proper.	Subsequently to the Experiment Proper.	Total Cost.
Lot 1	$1.66	$38.77	$3.69	$44.12
Lot 2	1.68	38.85	3.63	44.16
Lot 3	1.48	32.93	3.32	37.73
Lot 4	1.68	43.13	4.22	49.03
Totals	$6.50	$153.68	$14.86	$175.04

It will be noticed that during the experiment proper and subsequently, the cost of the food consumed by the lambs in lot 4 was considerably in excess of the cost of food for the lambs in any of the other lots. This was owing to the dearer prices, relatively, of the oats which made up so large a portion of the grain fed, and also to the dear price of the oil cake which was fed most freely to the lambs in this lot. The gains secured were somewhat ahead of those made by the lambs in any of the other lots, as is shown below. But the greater relative cost of the food fed far more than counterbalanced the greater increase made in weight, hence, considerably less profit was made on the lambs in this lot.

The cost of food was considerably less for the lambs in lot 3 than for any of the other lots, and yet, as shown below, the least profit was made from them. This arose from the smaller amount, relatively, of the grain food consumed, and from its failure to produce sufficient gains. This fact would seem to emphasize the close relation between a free consumption of food during the fattening period and good gains. The only reasonable explanation that can be given for the low consumption of food by these lambs as compared with the lambs in lot 2 is the absence of oil cake in their ration. In other respects the foods fed were similar, except that more bran was fed to the lambs in lot 3. More bran in the ration, therefore, would not seem to atone for the entire absence of oil cake.

Profits Made During the Experiment Proper.—Table LXX gives: 1. The value of the lambs in each lot at the commencement of the experiment proper; 2. The cost of food fed during the same; 3. The total cost of the lambs up to the close of the experiment proper; 4. The value of the lambs at the close of the experiment; and 5, the profit made on the lambs in each lot during the experiment.

TABLE LXX.—Profit Made During the Experiment Proper.

	Lot 1	Lot 2	Lot 3	Lot 4	Totals
Value on Nov. 8th, 1897....	$64.64	$63.79	$64.90	$63.67	$257.00
Cost of food.....	38.77	38.85	32.98	43.18	153 68
Total cost.....	$103.41	$102.64	$97.88	$106.80	$410.68
Value on Feb. 28th, 1898...	159 61	153.45	149 38	158 56	621.00
Profit.....	$56.20	$50 81	$51.55	$51.76	$210.32

In the above table the value put upon the lambs at the beginning of the experiment was their actual cost. And this would be very nearly the proper market value for such lambs at the time that these were bought. It was rather under, perhaps, than over average market values. At the close of the experiment they were valued at 5½ cents per pound, live weight, the price paid for them 12 days later. No allowance is made for shrinkage. Had such allowance been made, it would reduce the total profit during the experiment proper from $210.32 to $179.25. The less profit made on the lambs in lot 2 was owing to the loss of one lamb in that group, as previously stated. Taking that lamb at its full weight, 98 pounds, when it died, on Jan. 25th, and adding 7 pounds as the probable gain that it would have made before the close of the experiment, and then adding its value if alive to $50.80 the actual profit on the lambs in lot 2, the result, $56.58, would represent the highest profit made by the lambs of any one lot. This would indicate that barley, when not too dear, can be turned to excellent account in feeding lambs for the block.

Weights of the Lambs.—At the commencement of the experiment, each lamb was given an ear label, and was then weighed singly. As these labels were duly recorded, and also the individual weights at each successive period of weighing, it was easily possible to compare the gains made. While there was much difference in the increase in weight of individuals, there were only one or two instances of decided ill-doing. The highest individual increase in weight made was 48 pounds, and the lowest was 17 pounds.

Table LXXI. gives the aggregate weights of the lambs in each lot at the commencement of the preparatory experiment, at the beginning of the experiment proper, and at the date of shipment, with the totals in each instance.

TABLE LXXI.—Aggregate Weights of the Lambs.

	Lot 1	Lot 2	Lot 3	Lot 4	Totals
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weights on Nov. 1st, 1897..	1,824	1,795	1,837	1,795	7,251
Weights on Nov. 8th.....	1,848	1,835	1,843	1,813	7,339
Weights on Feb. 28th, 1898	2,902	2,790	2,716	2,883	11,291
Weights on March 12th.....	2,985	2,855	2,750	2,970	11,560

The increase in weight made by the lambs during the 131½ days in which they were being fed, was nearly 60 per cent. of the weight when the feeding period began. The weights of the lambs in lots 1, 2 and 4 would have been nearly even at the close of the experiment proper, but for the loss of the one lamb. Including its weight and probable gain, the aggregate weight of the lambs in lot 2 would have been 2,895 pounds.

Table LXXII. gives the average weight of the lambs in each lot when the preparatory experiment began, when the experiment proper began and closed, the average total increase in weight made by the lambs in each lot, and the aggregate total increase.

TABLE LXXII.—Average Weights and Average Gains.

	On Nov 1st, 1897.	On Nov. 8th.	On Feb. 28th, 1898.	Average Increase.	Aggregate Increase.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot 1.....	60.8	61.6	96.7	35.1	1,054
Lot 2.....	59.8	61.2	93.0	31.8	955
Lot 3.....	61.2	61.4	90.5	29.1	873
Lot 4.....	59.8	60.4	96.1	35.7	1,070

The greatest aggregate gains were made by the lambs in lot 4. Next comes lot 2 with the dead lamb accounted for. He weighed 98 pounds when he died, and would doubtless have gained 7 pounds more prior to the close of the experiment. Adding the 105 pounds thus obtained to 955 pounds, the aggregate gains made by the lambs in lot 2 would bring it up to 1,060 pounds. The third place is assigned to the lambs in lot 1. The gains thus made are remarkably uniform, except with the lambs in lot 3.

The average increase in weight made by the lambs in each lot in 30 days, that is to say, per month, is as follows:

	Pounds.
Lot 1	9.4
Lot 2	8.5
Lot 3	7.8
Lot 4	9.6

If the dead lamb is taken into the account the gains per month made by the lambs in lot 2 would be changed from 8.5 to 9.5 pounds. On this basis the average increase per month made by each lamb under experiment would be 9.07 pounds, and for the entire period of feeding, 8.3 pounds. These are not extraordinary gains, but in the absence of field roots in the ration, they are good average gains for so long a period of feeding.

It may also be noted here, that while, during the first half of the experiment, the lambs made an aggregate in-

crease in weight of 2,433 pounds, during the last half of the same, the increase made was but 1,724 pounds. The increase in the former period, therefore, exceeded the increase in the latter by 709 pounds. This fact would emphasize the importance of not feeding lambs for too long a period.

Increase in Value.—Table LXXIII. gives the cost of the food fed to the lambs of each lot during the experiment proper, the value of the increase in weight, and the profit on said increase.

TABLE LXXIII.—Increase in Value During Experiment Proper.

	Value of Food Fed.	Value of Increase in Weight.	Profit on Increased Weight.
Lot 1	$38.77	$57.97	$19.20
Lot 2	38.85	58.30	19.45
Lot 3	32.98	48.01	16.08
Lot 4	43.13	58.85	15.72

The dead lamb is included in this computation. The figures in the third column should certainly tend to encourage western feeders. It would be well-nigh if not quite impossible for eastern feeders to get results so satisfactory, owing to the higher relative value of the food stuffs with them.

Accounting for the dead lamb as above, the cost of making 100 pounds of increase with the lambs of each group during the experiment proper was as follows:

Lot 1	$3.68
Lot 2	3.67
Lot 3	3.77
Lot 4	4.03
Average Cost	$3.78

The greater relative cost of the increase made by the lambs in lot 4 emphasizes the importance of using cheap foods, since the lambs in lot 4 made the largest increase in weight.

Financial Statement.—A summary of the facts relating to the financial side of the whole transaction is now submitted:

Cash return for 119 lambs delivered to Peter Van Hoven, at New Brighton, Minnesota, on March 12th, 1898		$604.01
Cost of 120 lambs in Montana	$217.53	
Cost of freight	30.57	
Cost of pasture	2.40	
Cost of food in the preparatory experiment	6.50	
Cost of food during the experiment proper	153.68	
Cost of food subsequently	14.86	
Total outlay		$425.54
Profit on 120 lambs		178.47
Profit on each lamb		1.49

Observations.—1. It will be noticed that in the above computation, the lamb that died is charged against the experiment, and also the food eaten by him, nor is the 50 cents included that was received for his pelt.

2. The manure made is supposed to offset the value of the bedding, the cost of the labor, and the interest on the investment. Whether such a value put upon the manure is too dear must be determined by each farmer for himself.

3. It should also be borne in mind that the food fed was charged at market values. The market value of food is usually in excess of the home value of the same, that is to say, in excess of the cost of production. Charging it thus, therefore, is unfavorable to the experiment.

IMPORTANT FACTS SUMMARIZED.

Values—

1.	Price paid per hundred for the lambs in Montana	$3.00
2.	Value per hundred on the basis of cost, when the preparatory experiment began, Nov. 1st, 1897	3.45
3.	Value per hundred when the experiment proper began, Nov. 8th	3.41
4.	Value per hundred when the lambs were delivered at New Brighton, March 12th, 1898	5.50
5.	Difference per hundred between cost price and selling price	2.05

Freights—

1.	Cost of freight on each of the 299 lambs which were brought to the station	.23.3
2.	Cost of freight on each lamb in the experiment, computed on the basis of weights	.25.5
3.	Cost of freight on each wether of the shipment, computed on the basis of weights	.50.0
4.	Cost of freight on the double-deck car from Culbertson to St. Paul, 702 miles, with a cargo of 25 wethers and 299 lambs	82.10

Weights—

		Lbs.
1.	Average weight of 299 lambs, bought in Montana, on reaching the station	55.5
2.	Average weight of 120 lambs used in the experiment on reaching the station and when the experiment began, Nov. 1st, 1897	60.4
3.	Average weight at the close of the experiment proper, without shrink, Feb. 28, 1898	97.1
4.	Average weight when sent to the block, March 12th, with a shrink of 5 per cent	92.3

Increase in Weight—

		Lbs.
1.	Average increase in the weight of each lamb during the experiment proper	36.7
2.	Average increase per month during the experiment proper	9.07
3.	Average increase per month during the entire feeding period	8.30

Food Consumed—

1.	Average amount of food consumed per day by each lamb during the experiment proper	3.11
2.	Average amount of grain consumed per day by each lamb during the experiment proper	1.85
3.	Average amount of fodder consumed per day by each lamb during the experiment proper	1.26

Cost of Increase—

1.	Average cost of making 100 pounds of increase in weight during the experiment proper	$3.78
2.	Average cost of making 100 pounds of increase during the whole period of feeding	3.97

Profits—

1.	Average value of each lamb (120), at the beginning of the experiment, Nov. 1st, 1897	2.08
	Average value of each lamb at the close of the experiment proper, Feb. 28th, 1898, without shrink	5.22
2.	Average value of each lamb (119) at the close of the experiment, March 12th, 1898, with shrink	5.08
3.	Average advance in value over the cost made by each lamb during the entire feeding period	3.00
4.	The total net profit from feeding 120 lambs for 131½ days	178.47
5.	The total net profit from feeding one lamb	1.49
		Per Ct.
6.	The per cent. of profit on all money invested	.42

CONCLUSIONS.

The following are chief among the conclusions that may legitimately be drawn from the experiment:

1. That corn, barley and oats are about equally valuable in producing an increase in weight in lambs that are being fattened, when fed with suitable adjuncts.

2. That barley, not much used in fattening lambs in the Northwest, compares favorably with corn in feeding value when fed with suitable adjuncts.

3. That in fattening lambs, barley, without a small supplement of oil cake, is inferior to barley or to corn with a supplement of the same.

4. That the light gains made, relatively, by the lambs in lot 3, to which oil cake was not fed, and the correspondingly low profit, would seem to indicate the wisdom of feeding a small quantity of oil cake with barley, even when the price is relatively dear.

5. That the less net profit from the lambs in lot 4, notwithstanding that they stood first in the gains made, emphasizes the importance of weighing carefully the relative value of food, when choosing them for feeding uses.

6. That since, in the experiment proper, the average increase in the weight of each lamb per month was 9.07 pounds, good gains may be secured from range lambs when fattening them, in the absence of field roots.

7. That when, as in this experiment, 100 pounds of increase can be made for $3.78, and sold for $5.50, the farmers who feed lambs should make a much greater profit on the food so fed, as compared with selling it in the market.

8. That since in this experiment an added value of $3.00 was put upon range lambs which cost $2.08, by feeding them 131½ days, and at an outlay for food of $1.46, the question of fattening lambs is surely worthy of the careful consideration of the farmers of the Northwest.

AVERAGES FROM THREE EXPERIMENTS.

The following statements contain averages gleaned from the three experiments of the bulletin.

Period of Feeding—

	Days.
1. Average time covered by the preparatory feeding.	7
2. Average time covered by the experiment proper..	91
3. Average duration of the feeding period	98

Values—

1. Average value of the lambs per 100 pounds on the basis of cost when the feeding began.....	$3.45
2. Average value per 100 pounds, shrunk weight, when the lambs were sold.....	4.88
3. Difference per 100 pounds between the cost price and the selling price.....	1.43

Increase in Value—

1. Average value of each lamb when the feeding period began.....	2.65
2. Average value of each lamb at the close of the feeding period, without shrink.....	5.03
3. Average value of each lamb at the close of the feeding period, with shrink.....	4.87
4. Average increase in value of each lamb during the feeding period.....	2.38

Weights—

	Lbs.
1. Average weight of one lamb when the experiment proper began.....	72.2
2. Average weight of one lamb when the experiment proper closed, that is to say, from 91 days' feeding.....	105.8

Increase in Weight—

1. Average increase in weight of one lamb from 91 days' feeding.....	33.6
2. Average increase in weight per month of 30 days,	9.4

	Lbs.
3. Highest average increase in weight per month from all the lambs in a single experiment	12.0
4. Lowest average increase per month from all the lambs in a single experiment	7.1

Food Consumed—

1. Average of grain consumed per day by one lamb.	2.07
2. Average of hay consumed per day by one lamb...	.84
3. Average of food consumed per day by one lamb..	2.92

Cost of Increase—

1. Average cost of making 100 pounds of increase in weight during the experiment proper	$3.59
2. The lowest cost of making 100 pounds of increase by the lambs of any one lot	2.92
3. Average increase in value per 100 pounds, of the added weight, over the cost of producing it during 91 days of feeding	1.29

Profit—

1. Average profit on one lamb during the experiment proper (91 days), shrunk weight not included	1.08
2. Average profit on one lamb during the experiment proper (91 days), shrunk weight considered	.96
3. Average net profit per lamb during the entire period of feeding	.86

CONCLUSIONS.

The following are some of the more important of the conclusions that may be drawn from the three experiments:

1. That both range lambs and home-grown lambs are well adapted for feeding.

2. That the value of the increase made from feeding lambs in our state is more than the cost of the food used in making it.

3. That the coarse cereals which Minnesta produces are well adapted to the fattening of lambs when suitably blended.

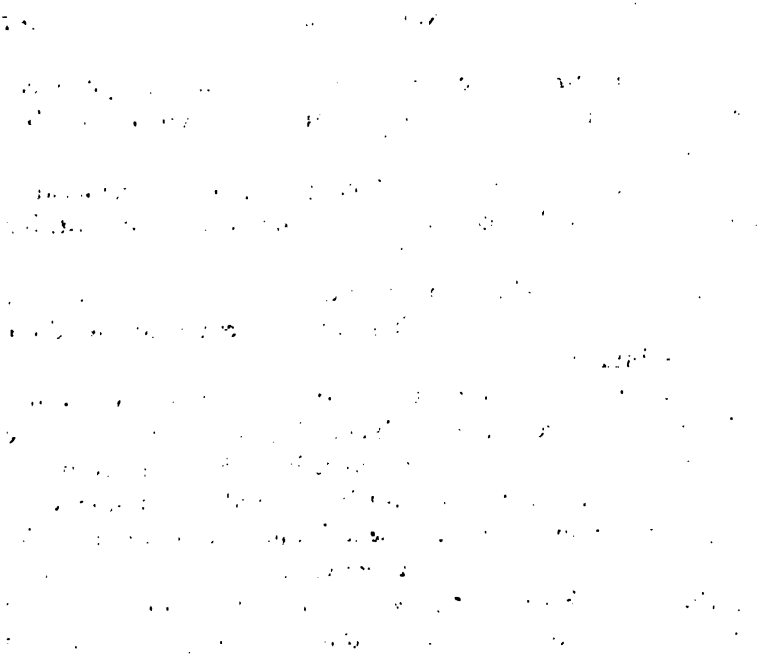
4. That when lambs are being fattened, considerably superior gains will be obtained when the grain food contains at least 10 per cent. of oil cake.

5. That oil cake, barley and oats, suitably blended, with or without bran, makes an excellent grain food for fattening lambs.

6. That while good gains may be secured by feeding oats and oil cake, suitably blended, the dearness of the mixture makes it too costly to furnish the highest profit.

7. That excellent gains can be secured when fattening lambs in our climate in the absence of field roots or ensilage.

8. That under the conditions which have prevailed during the past three years, an average of about $1.00 per head could be secured from feeding lambs judiciously for about 100 days.



FATTENING MINNESOTA STEERS.

SECTION NO. 1.

THOMAS SHAW.

This bulletin contains the results of two experiments in feeding steers conducted essentially on the same lines and with the same object in view, but with some slight variations in the foods used. The chief object of the experiments was to glean information bearing upon the amount of grain, approximately, that would bring the greatest value when fed along with such fodder as corn, ensilage and hay. The chief variations consisted in some modifications in the kinds of grain used, in the proportions of these, and in the source whence the steers were secured. In Section No. 1, they were farm-grown steers, but in Section No. 2, they were reared on the range.

On coming West, the attention of the writer was early drawn to the custom which seemed to prevail everywhere of feeding what seemed to be extravagantly large amounts of grain. As much as 25 pounds of corn and even more than that quantity was usually fed per day to one steer of 1,000 pounds weight and upwards, when followed in the feed lot by one pig. Now, suppose the pig is allowed 5 pounds per day, which would seem to be a fair allowance, there is still left for the steer 20 pounds, and more than that in proportion as the grain is increased beyond 25 pounds per day, for the steer and the pig, as much more as the increase exceeds the amount named. This to the writer appeared to be extravagant feeding, and to the degree of being positively wasteful, in fact a style of feeding that could not be sustained in any country in which the prices of coarse grains have become relatively dear. True, these prices have usually been cheap in this western land of bountiful production. But it will not be so always, nor indeed is it probable that

the era of prices so low will ever come to us any more. These prices are even now making a sharp advance. They may fall again. Doubtless they will. But we may rest assured that the normal level of the prices for coarse foods will gradually go upward. This has been the experience in all the past in newly tilled areas as their tillage grows o der. Viewed from such a stand point, the principle involved in these experiments assumes an importance that cannot well be over-estimated. If the assumptions of the writer should prove to be correct, first, with reference to the extravagance of western feeding, and second, with reference to the probable advance in the prices of coarse fodders, it would mean that sometime in the not distant future, our methods of feeding will have to be so modified as to amount to what may be termed a revolution in the same. I know very well that the sentiments just expressed will not meet with the approval of many, but I make them all the same, under the firm conviction that the future will justify the stand taken.

To throw some light on the economics of this question these experiments have been engaged in; with that object in view they have been prosecuted from year to year. And with the same object in view, with the concurrence and approval of the authorities of the University, they will still be continued in one form or the other until the views advanced shall have been sustained or disproved, as the case may be.

Time Covered by the Experiment.—The feeding began January 6th, and ended June 4th, 1896. It thus covered a period of 150 days. The lateness of the season at which the feeding began arose from the difficulty of securing the steers. It was sought to obtain them in the state. Although one of the three lots was purchased as early as September 1st, 1895, the animals in the third lot were not secured until the opening of the following year. In this we have an evidence of the relative limited production of good feeding-animals in the state. The difficulty of the effort was further enhanced by the high prices which had been paid for finished

animals the previous spring, and which had the effect of causing holders to rate their store animals at a price that could not be paid for them for successful feeding.

The Objects Sought in the Experiment.—Chief among the objects sought in the experiment were the following: 1, to ascertain the relative maximum increase from feeding light, moderate or heavier quantities of grain to steers that are being fattened during a somewhat prolonged term of feeding; 2, to ascertain the relative financial outcome from such feeding; and, 3, to ascertain the relative merit in steers of different grades for being thus fed. The secondary objects sought to learn: 1, the relative daily gains made; 2, the relative amounts of food consumed in making them; and, 3, the relative cost of producing these gains.

The Animals Used.—The aim was to secure three lots of animals, with three in each, that would be fairly representative of good grades of the Shorthorn, Hereford and Aberdeen Poll breeds. They were to be two years old, of common cows of mixed breeding, but having a bearing to beef in their tendencies, and from a pure bred sire. All these objects were at length measurably realized, although it was not possible to get much information about the dams.

The Aberdeen Poll grades were purchased from David M. Fyffe, manager of Wavertree farm, Dundee, Minnesota. They reached the farm Sept. 8th, 1895, and were kept on blue grass pasture until early in November. From October 3rd, they were fed hay in increasing amounts as they would take it until the experiment began. On October 28th, they were housed at night, and beginning with November 3rd they were fed 4 pounds per head per day of grain, and without increase until January 6th, when the experiment began. The grain fed consisted of bran and ground corn fed in the proportions of 2 and 1 parts by weight. The aggregate weight of the steers when they reached the station was 2,620 pounds and the average weight was 873.3 pounds. They gained in the interval named 415 pounds. They were muleys

and black or iron gray in color. The average price paid for them at Dundee was 3⅝ cts. per pound. The freight was charged at 18 cents per 100 pounds which was the rate charged for carload lots. But 50 cents per animal was allowed for pasture, as it was inferior, and during much of the time while the steers were on pasture, other food was fed to them. Adding $89.43, the cost in Dundee; $4.72, the estimate for freight; and $7.59, the cost of food and pasture, gives $101.74 as the cost of the steers on January 6th, 1896. The net cost therefore was $3.35 per 100 pounds.

The three Shorthorn grades were bought at the South St. Paul stock yards, from E. M. Prouty & Co. They had been reared in North Dakota and were evidently well up in Shorthorn blood. They reached the Station October 25th, and were managed exactly in the same way as the Galloways described above, until the commencement of the experiment on January 6th. The aggregate weight on arrival was 3,180 pounds, and the average weight 1,060 pounds. Subsequently and prior to the beginning of the feeding period they gained 245 pounds. The price paid at South St. Paul was $3.65 per 100 pounds. Adding $116.07 the cash price at the stock yards, $3.13 commission, feed and yardage charges, and $6.61 for food fed prior to the experiment, gives the sum of $125.81 as the cost of the steers when the experiment began. The cost per 100 pounds therefore was $3.67.

The three Hereford grades were purchased from M. Tousley, of Le Sueur, Minn. They reached the station on January 3d, 1896. They weighed together 2,940 pounds, an average of 980 pounds. They gained 20 pounds during the three following days. The price paid at Le Sueur was $4.00 per 100 pounds. The freight was charged at 11 cents per 100 pounds, the charge for carload lots. Adding $117.60 the cash price paid at Le Sueur, 88 cents the food for three days, and $3.23 for freight, gives $121.71 or $4.11 per 100 pounds as the cost of the Herefords. The net cost

of the nine steers therefore, when the experiment began, was $3.70 per 100 pounds.

Conditions Governing the Experiment.—Nine steers in all were put under experiment, that is to say, three animals of each grade. They were tied in stalls. Those of each grade stood side by side, and when any comparisons are made relating to breed they are spoken of in the experiment as Aberdeen Polls, Shorthorns and Herefords respectively. When comparisons other than these are made, they refer to lots and not breeds, as such. Lot 1 comprised the three steers that stood on the right hand of the breed groups, one of each. Lot 2 comprised those standing in the centre, and lot 3 those standing on the left. To the steers in lot 1 was fed the light grain food referred to further on, to those in lot 2 the intermediate grain portion, and to those in lot 3 the heavier grain food. The steers were curried occasionally. They were given exercise for a short time in a yard on fine days. The practice was to turn out those of each lot on alternate days, only one lot being out on one day. They were weighed when the experiment began and every week thereafter.

Food and Feeding.—The steers in lot 1 were fed 5 pounds of meal per head per day; the steers in lot 2, 7 pounds; and those in lot 3, 9 pounds. This was to be increased 1 pound per animal at the end of every 4 weeks, but for reasons not quite in consonance with the judgment of the writer, it was increased a little faster than that. On February 10th a pound of oil-cake was added, per animal per day, to the other meal. On March 16th a second pound was added. On May 11th the maximum amounts of meal fed had been reached. These were 10, 12 and 14 pounds respectively, for the steers of the different lots. The meal fed consisted of equal parts by weight of bran, oats, barley and corn. On March 16th the grain food was changed to bran, barley and corn, in the proportions of 1, 1 and 2 parts by weight.

In addition to the grain, each steer was fed 25 pounds of corn ensilage per day throughout the experiment, and in addition they were given all the native hay which they would consume cleanly. The ensilage was medium or a little less than that, but the hay was decidedly inferior in quality. The grain was fed along with the ensilage morning and evening, and the hay was given in three feeds daily. Water was given in pails twice a day, and salt was given in the mangers at least two or three times per week.

The Herefords were dehorned when they entered the experiment. The dehorning interfered with their feeding somewhat seriously at first, and it was more than 14 days thereafter before the effects of the dehorning entirely vanished. This was of course so far unfair to the Herefords in the contest.

Estimated Value of the Food.—The food was charged at what was considered average market values in the state. These were as follows:

Bran, per ton	$6.50
Oil-cake, per ton	14.00
Oats, per bushel of 32 pounds	.14
Barley, per bushel of 48 pounds	.16
Corn, per bushel of 56 pounds	.18
Native hay, per ton	3.00
Corn ensilage, per ton	1.00

As the oats, corn and barley were fed in the ground form, the ordinary cost of grinding, viz. 5 cents per sack, was allowed. The price of these grains in the ground form, therefore, was 16½, 20½ and 18½ cents per bushel.

The above estimate for foods to an Easterner may seem almost ridiculously low. But in some instances the food cost less than the prices charged. The bran was bought in the mills of the Twin Cities for $4.50 per ton. In various parts of the state oats were exchanging hands at 9 to 11 cents per bushel. True, the price of meat was low in the spring of 1896, but, with that exception, the prices paid for

meat were not really low during the term of years in which such low prices for food prevailed. The opportunities therefore to make money from the judicious feeding of live stock during those years were exceptional. But with nearly all our farmers they were not improved. Like the waters that were allowed to pass without grinding the grist, they also have passed for the prices of foods are likely to be higher for years to come.

Food Consumed.—Table LXXIV. gives the amount of hay, ensilage and meal respectively consumed by each steer during the experiment, and the amount of these combined, also the total of each kind of food and of all the food consumed by the steers of each lot.

TABLE LXXIV.—Food Consumed by the Steers.

	HAY.	ENSILAGE.	MEAL.	TOTAL.
LOT No. 1—	Lbs.	Lbs.	Lbs.	Lbs.
Galloway	890	3,654	1,283	5,827
Shorthorn	1,287	3,650	1,297	6,234
Hereford	933	3,066	1,283	5,282
Total	3,110	10,370	3,863	17,343
LOT No. 2—				
Galloway	904	3,589	1,578	6,071
Shorthorn	1,126	3,652	1 587	6,365
Hereford	909	2,556	1,549	5,014
Total	2,939	9,797	4,714	17,450
LOT No. 3—				
Galloway	771	2,353	1,830	4,954
Shorthorn	978	3,373	1,763	6,114
Hereford	820	2,403	1,782	5,005
TOTAL	2,569	8,129	5,375	16,073

Each steer was given the same amount of oilcake, viz. 196 pounds, and it is included in each instance in the aggregate amount of meal fed. It will be observed that the increased quantity of meal fed to the steers in lots 2 and 3 respectively, caused a somewhat decreased consumption of both hay and ensilage, as compared with the amounts of these

consumed by the steers in lot 1, but the decrease was not sufficient to balance the greater cost of the additional grain fed. In fattening animals there is a point at which the respective quantities of fodder and meal fed are in equilibrium. The best results will unquestionably be obtained when that point is reached.

Table LXXV. gives the amount of each kind of food consumed daily by the steers in the different lots, the average amount of the same, and the total daily consumption of food by each individual animal.

TABLE LXXV.—Daily Consumption of Food by the Steers.

	Hay	Ensilage	Meal	Total
Lot No. 1—	Lbs.	Lbs.	Lbs.	Lbs.
Galloway	5.93	24.36	8.55	38.84
Shorthorn	8.58	24.33	8.65	41.56
Hereford	6.22	20.44	8.55	35.21
Average	6.91	23.04	8.58	38.54
Lot No. 2—				
Galloway	6.02	23.93	10.52	40.47
Shorthorn	7.51	24.35	10.58	42.44
Hereford	6.06	17.04	10.33	33.43
Average	6.53	21.77	10.48	38.78
Lot No. 3—				
Galloway	5.14	15.69	12.20	33.03
Shorthorn	6.52	22.49	11.75	40.76
Hereford	5.47	16.02	11.88	33.37
Average	5.71	18.07	11.94	35.72

It will be noticed, first, that the averages of meal consumed daily by the steers in the different lots were 8.58, 10.48 and 11.94 pounds respectively; second, that the steers in lot 3 did not consume quite the full proportion of meal intended for them, although at no time of the experiment were they given more than 16 pounds per day, more than once the quantity given to them had to be modified to keep them on their feed; third, that the average quantity of meal fed to the steers in lot 1 was only a little more than

one-third of the average quantity of corn fed by our western feeders. True, there was some corn fed in the ensilage. This fact must not be lost sight of, but the amount of corn thus fed would not amount probably to more than two or three pounds per day, and yet, as will be shown later, the increase made by the steers in lot 1 is more than the increase made by those in lot 3, which consumed so much more grain; and, fourth, that the steers in some of the lots consumed quite the amount of ensilage intended. This was due to its indifferent character, otherwise they would have eaten it clean in preference to the poor hay given. Notably was this the case with the steers in lot 3, which were given so much grain.

Weights of the Animals.—Table LXXVI. gives the weight of the individual animals in each lot at the commencement and at the close of the experiment, and the total individual increase in weight. It also gives the total for each group.

TABLE LXXVI.—Weights of the Animals in the Different Lots.

	Weight at the Beginning of the Experiment	Weight at the Close of the Experiment.	Total Increase in Weight.
LOT No. 1—	Lbs.	Lbs.	Lbs.
Galloway	1,000	1,247	247
Shorthorn	1,080	1,342	262
Hereford	1,080	1,262	282
Total	3,110	3,851	741
LOT No. 2—			
Galloway	1,050	1,317	267
Shorthorn	1,180	1,422	242
Hereford	935	1,202	267
Total	3,165	3,941	776
LOT No. 3—			
Galloway	985	1,247	262
Shorthorn	1,160	1,375	215
Hereford	995	1,210	215
Total	3,140	3,832	692

The aggregate gain made by the steers in lot 1 was 35 pounds less than that made by the steers in lot 2, but it was 49 pounds more than that made by the steers in lot 3, notwithstanding the much greater consumption of meal by the latter, and meal is usually the most costly food. These results would tend to show that gain can't be forced in a somewhat prolonged period of feeding by giving concentrated food beyond a certain limit.

Table LXXVII. gives the average daily gains made by the individual animals in the several lots and also the daily average made by those of each lot.

TABLE LXXVII.—Average Daily Increase Made.

	Lot 1	Lot 2	Lot 3
	Lbs.	Lbs.	Lbs.
Galloway	1.65	1.78	1.76
Shorthorn	1.75	1.61	1.43
Hereford	1.55	1.78	1.43
Average	1.65	1.72	1.54

The average daily gain made by all the steers was 1.64 pounds. This is only a moderate increase, but it is probably about as good as may usually be looked for from prolonged feeding in the absence of ensilage first-class in quality. The fact is significant that the extra amounts of meal fed to the steers in lot 3 did not produce the greatest gains.

Cost of Food.—Table LXXVIII. gives the cost of each food factor fed to the individual animals in the different lots, the total cost of the several food factors fed to each, and the total cost of the food fed to the animals of the respective lots.

TABLE LXXVIII.—Cost of Food Consumed.

	Hay.	Ensilage.	Meal	Total
Lot No. 1—				
Galloway	$1.34	$1.83	$5.53	$8.70
Shorthorn	1.93	1.82	5.49	9.24
Hereford	1.40	1.53	5.43	8.36
Total	4.67	5.18	16.45	26.30
Lot No. 2—				
Galloway	1.36	1.80	6 45	9.61
Shorthorn	1.69	1.83	6.58	10.10
Hereford	1.36	1.28	6.44	9.08
Total	4.41	4.91	19.47	28.79
Lot No. 3—				
Galloway	1.16	1.18	7.49	9.83
Shorthorn	1.47	1.68	7.24	10.39
Hereford	1.23	1.20	7.31	9.74
Total	3.86	4.06	22.04	29.96

The food fed to the steers in lot 1 cost $2.49 less than that given to those in lots 2 and $3.66 less than that given to the steers of lot 3, while the increase in the weight of those in lot 2 as previously stated was only 35 pounds more than with those in lot 1, and with the steers in lot 3 it was 49 pounds less. With food at normal prices the difference in the cost of food could have been much greater. It is also worthy of notice, that the shorthorn steers of lots 2 and 3 respectively did not make the greatest increase in weight, although they cost the most for food.

Table LXXIX. gives the average daily cost of the food consumed by the individual animals in the several lots, and also the daily average cost of the same by lots.

TABLE LXXIX. Average Daily Cost of Food Consumed.

	Lot 1.	Lot 2.	Lot 3.
	Cents	Cents	Cents
Galloway	5.80	6.41	6.55
Shorthorn	6.16	6.73	6.93
Hereford	5.58	6.05	6.49
Average	5.83	6.40	6.66

The average cost of feeding each steer per day for the 150 days of the experiment was but 6.3 cents. Such a result seems scarcely credible to one used to the more costly feeding of the East. In the winters of 1890, '91 and '92 the writer fed steers in Ontario with a daily average outlay for food of 17.59 cents, and with a fair profit. Of course the relative buying and selling prices were different. Had the prices of meat been normal when the steers fed in this experiment were sold, the profit made would have been satisfactory, even at the high price paid for them.

Cost of Increase.—Table LXXX. gives the average cost of making each 100 pounds of increase by the individual animals in the several lots, and also the average cost of the same by lots.

TABLE LXXX.—Average Cost of 100 Pounds of Increase.

	Lot 1	Lot 2	Lot 3
Galloway	$3.52	$3.60	$3.75
Shorthorn	3.53	4.17	4.83
Hereford	3.60	3.40	4.53
Average	$3.55	3.72	4.37

The average cost of producing 100 pounds of increase by the steers in all the lots was $3.88. They were sold at the abnormally low price of 4.10 cents per pound when finished, but even at that low price each average pound of increase was made at a figure less than the cost of making it; with four of the animals only was it greater, and it is significant that three of the four were in lot 3, and that one of them was in lot 1.

Profit Made.—Table LXXXI. gives: 1, the value of the steers in each lot when the experiment began; 2, the cost of the food fed; 3, the total outlay; 4, the value when the experiment closed, and, 5, the profit. The totals in each instance are also given.

TABLE LXXXI.—Values and Profit Made During the Experiment.

	Lot 1	Lot 2	Lot 3	Totals
Value when the Experiment began Jan. 6, '96..	$115.07	$117.11	$116.18	$348.36
Cost of Food.....	26.30	28.79	29.96	85.05
Total Cost.....	141.37	145.90	146.14	433.41
Value when the Experiment closed June 4.....	157.89	161.58	157.11	476.58
Profit.....	$16.52	$15.68	$10.97	$43.17

No allowance is made for shrink in the above computation. Nor should it be in such a statement, without also shrinking the animals at the beginning of the feeding. The above profit is of course greater than the net profit shown later. Nor should the fact be overlooked that the profit during the feeding period was $5.55 more from the steers in lot 1 than from those in lot 3, although each of the latter consumed daily 3.36 pounds more meal.

Table LXXXII. gives the value of the food fed during the experiment, the value of the increase made, and the profit or otherwise of the said increase.

TABLE LXXXII.—Profit from the Increase Made During the Experiment.

	Value of Food Fed	Value of Increase in Weight	Profit on the Increase in Weight
Lot 1.....	$26.30	$30.38	+$4.08
Lot 2.....	28.79	31.82	+ 3.03
Lot 3.....	29.96	28.37	— 1.59
Totals.....	$85.05	$90.57	+$5.52

The net profit, $5.52, on the increase in weight was not large, but under the circumstances it was very satisfactory to have any profit at all on the increase in weight.

Disposal of the Steers.—The steers were sold by Col. W. M. Ligget, the director, to W. E. McCormick, of St. Paul, through whom they were in turn sold to the retail trade of the city. The price paid was $4.10 per 100 pounds, with a

shrink of 4 per cent. They were sent to the block on June 4th, when the experiment closed.

Financial Statement.—Cash received for 9 steers on June 4th, 1896, shrunk weight 11,159 pounds at $4.10 per 100 pounds		$457.52
Value of 9 steers on Jan. 6th, on the basis of cost	$348.36	
Cost of Food	85.05	
Total outlay		433.41
Total net profit		$24.11
Net Profit on one steer		2.68

Observations.—1. Notwithstanding the high price paid for the steers and the low price received for them, some net profit was made on each animal. In lot 1 the net profit was $10.21; in lot 2, $9.20; and in lot 3, $4.70.

2. The value of manure is supposed to offset the cost of bedding, labor and interest on the investment.

3. The food was charged at market values, which ordinarily would be against the experiment, but at the figures named it was probably but little above the cost of production.

IMPORTANT FACTS SUMMARIZED.

Values.—

1.	Value per 100 pounds on the basis of cost, when the experiment began Jan. 6, 1896	$3.70
2.	Value per 100 pounds on the basis of actual receipts, June 4, when the steers were sold	4.10
3.	Advance in value per 100 pounds	.40

Weights.—

1.	Average weight of the steers in lot 1 when the experiment began, Jan. 6th, 1896	Lbs. 1,037

	Lbs.
2. Average weight of the steers in lot 2 at the same date	1,055
3. Average weight of the steers in lot 3 at the same date	1,047
4. Average weight of one steer in all the lots at the same date	1,046
5. Average weight of the steers in lot 1 at the close of the feeding, June 4th, 1896	1,284
6. Average weight of the steers in lot 2 at the same date	1,314
7. Average weight of the steers in lot 3 at the same date	1,277
8. Average weight of one steer in all the lots at the same date	1,292

Increase in Weight.—

1. Total increase in weight made by the steers in lot 1 during the experiment	741
2. Total increase in weight made by the steers in lot 2 during the same period	776
3. Total increase in weight made by the steers in lot 3 during the same period	690
4. Average increase per day made by the steers in lot 1 during the experiment	1.65
5. Average increase per day made by the steers in lot 2 during the same period	1.72
6. Average increase made by the steers in lot 3 during the same period	1.54

Food Consumed—

1. Average amount of meal consumed per day by the steers in lot 1 during the experiment	8.58
2. Average amount of meal consumed per day by the steers in lot 2 during the same period	10.48
3. Average amount of meal consumed by the steers in lot 3 during the same period	11.94

Cost of Food—

	Cents.
1. Average cost of food per day with the steers in lot 1	5.85
2. Average cost of food per day with the steers in lot 2	6.40
3. Average cost of food per day with the steers in lot 3	6.66

Cost of Increase—

1. Average cost of making 100 pounds of increase with the steers in lot 1	$3.55
2. Average cost of making 100 pounds of increase with the steers in lot 2	3.72
3. Average cost of making 100 pounds of increase with the steers in lot 3	4.37

Profits.

1. Net profit on the steers in lot 1	10.21
2. Net profit on the steers in lot 2	9.20
3. Net profit on the steers in lot 3	4.70
4. Average net profit on each steer	2.68
5. Net profit on the nine steers fed	24.11

SUMMARY BASED ON BREED.

1. The average weight of the Galloways, Shorthorns and Herefords respectively at the commencement of the experiment January 6, 1896, was 1,012, 1,140 and 987 pounds.
2. The average increase in weight per animal was 259, 240 and 238 pounds.
3. The average of food consumed per day was 37.45, 41.59 and 34.00 pounds.
4. The average cost of food was $9.38, $9.91 and $9.06.
5. The average cost of 100 pounds of increase was $3.62, $4.18 and $3.84.

6. The average net profit was $9.58, $6.62 and $7.91. In the breed contest therefore the Galloway grades are in the lead in point of gain, in cheapness of production and in the net profit made. Too much must not be made of this, however, as the weight of the Shorthorns at the beginning of the experiment indicated greater age, which if true, would be against them. And the dehorning of the Herefords would be so far against them. The result, however, tends to show the excellence of the hardy Galloway breed for meat production when crossed upon commoner grades.

CONCLUSIONS.

1. That this experiment demonstrates the marked suitability of animals of the Galloway cross for producing beef.

2. That in this experiment feeding meal beyond 10.58 pounds per animal per day with the other adjuncts failed to produce any greater relative increase in weight.

3. That in this experiment the highest net profit was made from the steers which were fed an average of but 8.58 pounds of meal daily with other adjuncts.

4. That in this experiment the cost of production was lowest with the steers which were fed the lowest quantities of meal.

5. That in fattening cattle they will consume more meal if given to them, than they seem able to digest and assimilate properly.

6. That in view of these facts when suitable fodder is fed along with the meal, it is not necessary to feed quantities of the latter so large as are usually fed in the feed lots of the west.

FATTENING RANGE STEERS.

SECTION NO. 2.

THOMAS SHAW.

The fattening of steers grown upon the range has heretofore received almost no attention from the farmers of the state. Something had been done in this line at the stockyards, but rather after a wholesale fashion, hence no exact details could be secured as to the suitability of range steers for being fattened under farm conditions such as are found in our state. Much less could information be gleaned with reference to the financial outcome from such feeding.

As is generally known, cattle have been grown for many years on the western ranges and in numbers very large in the aggregate. The range conditions, though suitable for growing them, are not suitable for fattening them without supplemental food. More especially is this true of the cattle grown on the ranges to the west of Minnesota. If, therefore, they are to be sent to the market in the best of finish, they must needs be fattened somewhere between the ranges and the place of slaughter.

These animals cross our state in thousands and tens of thousands every year while being sent to the market. Minnesota, better than almost any other state in the Union has facilities for fattening these animals. This statement cannot be gainsaid when climate, material to provide shelter and food production are considered, and several of the railroads which transport these cattle to market allow them to be fed in transit, which makes it possible for the feeder to enjoy the benefit of the long haul rates. The Minnesota farmer therefore enjoys exceptional advantages for engaging in such work, and this experiment was undertaken in the hope of gleaning such information as would demonstrate to

him not only its practicability but its advantageous character. It was also decided to so feed them if found practicable that the experiment would be of the same character as the two previously conducted, that is to say, it would prove a further demonstration of the results to be expected from feeding small, intermediate and larger quantities of grain while the animals were being fattened. The details of the first of these experiments are given in Bulletin No. 44, and those of the second form the first division of this bulletin.

Time Covered by the Experiment.—The experiment proper began December 7th, 1896, and ended April 17th, 1897, thus covering a period of 131 days. It was, however, preceded by what may be termed a preparatory period, which began Nov. 19th, and which therefore lasted 18 days. In the case of these steers this preparatory feeding was very necessary, that they might become accustomed to surroundings which to them were new and peculiar, and that they might be enabled to take hold of their food rations with some degree of uniformity when the experiment began. These rations were the same in kind as those fed during the experiment proper, described below. By the end of the preparatory period they were all taking their food fairly well, though in some instances they were not taking a full allowance of ensilage.

The Objects Sought in the Experiment.—Chief among the objects sought were: 1, to assertain the suitability of range-grown steers for being fattened under farm conditions; 2, to ascertain the relative returns from feeding light, intermediate and heavier quantities of grain, and, 3, to glean information bearing upon the probable financial outcome from conducting such work. The secondary objects sought information: 1, on such points as the relative daily gains made; 2, the relative amounts of food consumed in making them, and, 3, the relative cost of production.

The Animals Used.—Nine steers were used in the experiment. They were part of a carload of 21 animals purchased by the writer on "Shelter Ranch," Montana. Mr. John Manning, the owner of this ranch is located some 12 miles north from Culbertson, on the Great Northern Railroad. They were two-year-olds and were of various grades. In some, Hereford and Aberdeen Polled blood was evidently dominant, but in others, Shorthorn blood prevailed. They were good fair types of beef-making steers, but were a little long of limb and strong of bone to be placed in the very first rank. They were reared under what may be termed semi-range conditions, that is to say, they were grown on range pastures, but under the eye of a herder. They had been suckled by their dams, and in the winter, when necessary, hay had been given to them. They had never been handled otherwise than in branding them, and on all occasions had been driven by the aid of a horse. They were not so wild, therefore, as steers reared on the open range, but were very much wilder than those grown on the arable

Fig. 202.—Range Steers on Arrival at Crookston.

farm. With reference to the absence of handling, they were types of what a majority of the range cattle are soon likely to be, as the era of growing cattle on the semi-range plan rather than on the open range and without a herder is evidently at hand.

The steers were unloaded at the sub-experiment station at Crookston on September 2, 1896. As pasture was abundant there, it was the intention to graze them for a time, and to feed them likewise a supplement of cheap grain, such as screenings. It cannot be said, however, that this part of the experiment was quite successful. The weather turned unusually cold for the season of the year, early frost destroyed the succulence of the grass, and in the absence of shelter the steers made but little increase, as will be apparent on examining the record of weights given below.

On November 18th they were reshipped to St. Paul, and on the 19th of the same 9 of them were weighed, tied up and put under experiment. These 9 were chosen on the basis of uniformity, and they were very little heavier than the average of the whole lot. The 12 animals remaining were divided into small lots of 3 each, and were put into close box stalls, to be fattened loose on certain rations allotted to them. But as one and another of them was slaughtered from time to time for the school of agriculture, comparisons could not be made that would be of any value.

When the steers reached Crookston they were weighed and evidently in a much shrunken condition. The average of the whole lot was 1,097 pounds. The average weight of the 9 animals subsequently put under experiment was 1,109 pounds. The average weight of the latter on November 19th, when the feeding began, was 1,129 pounds, and on December 7th, when the experiment proper began, it was 1,166 pounds. They were also dehorned at the time of the first weighing.

The cost in Montana was $30.00 per animal. On the basis of the weight taken at Crookston, they cost $3.10 per

100 pounds laid down at the latter place. The value of pasture was very low at the time at Crookston, as were also the values of hay and screenings. In fact these were simply nominal. From the time of arrival at the central station on November 18th, they were fed the same kinds of food as during the experiment proper. As they were fed together at Crookston, it is impossible to tell the exact cost of keeping each steer while there. But allowing market values for the food and pasture, as nearly as can be ascertained, they were worth on December 7th, when the experiment proper began, on the basis of cost, $3.13 per 100 pounds. This includes all outlay. The freight on the car from Culbertson, Mont., to St. Paul, 702 miles, was $83.50, and with food included, $84.90, practically $4.04 on each animal.

Conditions Governing the Experiment.—When put under experiment they were tied in stalls side by side. Tying them was no easy task, and some individuals apparently chafed under the confinement for a time, but gradually even these became quite contented with their surroundings. Although they at length became sufficiently tame to admit of being curried occasionally, the attendant had to exercise due caution in a near approach to some of them, even to the end of the experiment. The proper way, of course, to feed such animals on the farm would be at large with access to a shed and yard, but under such conditions some of the objects sought in this experiment would not have been obtained. The steers were weighed every two weeks after having been put under experiment. Under the circumstances it was not practicable to give them any exercise.

They were divided into three lots, three in each lot. The three right hand steers in the several lots taken together are spoken of as lot 1; the three middle steers are spoken of as lot 2, and the three left hand steers as lot 3. The first, second and third steers in each lot are also spoken of as (a), (b) and (c) respectively, when being distinguished in-

dividually. To the first, that is to say to lot 1, was fed the light meal portion, to the second the intermediate quantity, and to the third the heavier meal portion.

Food and Feeding.—The food consisted of bran, barley, corn and oilcake fed in the proportions of 3, 3, 3 and 1 parts by weight, hay and ensilage. The steers in lot 1 were fed 7 pounds per day of the grain when the experiment began, those in lot 2 were given 9 pounds, and those in lot 3, 11 pounds. These respective amounts were increased at the rate of one pound per animal every four weeks. It was intended to give them 25 pounds of corn ensilage per day per animal, but after a time some of them became so indifferent about eating the ensilage, that in order to sustain as nearly as practicable an equilibrium in the amounts of ensilage fed, the average per animal was reduced to 18 pounds per day on February 1st, and from the steer (a) of lot 2, it had to be withheld altogether. They were given all the mixed hay they would consume. The ensilage was fed in two feeds per day and likewise the meal. The hay was fed uncut and in three feeds per day. The contest lay between different quantities of meal fed to the steers of the different lots.

Estimated Value of the Food.—The food given to the steers was charged at what was considered average market values for the same in the state. These were as follows:

Bran, per ton	$6.50
Barley, per bushel of 48 pounds	.16
Corn, per bushel of 56 pounds	.18
Oilcake, per ton	14.00
Hay, per ton	3.50
Corn Ensilage	1.25

An allowance of 2½ cents per bushel was made for grinding the barley and corn. The ordinary charge for the same in the state is 5 cents per sack. The barley meal, therefore, would be worth 18½ cents per 48 pounds and the corn 20½

cents per 56 pounds. The hay was coarse in character. It consisted of timothy and clover, the former predominating.

Incidents of the Experiment.—On February 17th the grain ration was increased one pound per animal per day over and above the original intended ratio of increase. This increase was not quite in consonance with the judgment of the writer. By March 1st the respective amounts fed to each animal per day was, to the steers in lot 1, 11 pounds; in lot 2, 13 pounds, and in lot 3, 15 pounds. The meal was not further increased. On the other hand it was found necessary in some instances to decrease it. For instance, the steer (a) in lot 2, was off his feed for several days subsequent to March 18th, although he was being given but 11 pounds of meal daily. The meal fed to steer (c) in lot 2 must needs be reduced from 15 to 13 pounds daily for a few days subsequently to April 5th, and a similar reduction was found necessary with the steer (c) in lot 3, at least for a time, subsequently to April 5th. The meal fed to this steer after that date was never raised again to exceed 14 pounds daily. None of the steers consumed the full amount of ensilage intended. No ensilage was fed to the steer (b) in lot 1 after March 16th, as he refused to eat it, and steer (b) in lot 3 had also but little relish for the ensilage at any period of the feeding. On March 29th the barley was omitted from the ration and the proportions of the bran, corn and oil cake were made to consist of 3, 6 and 1 parts respectively. The change was made with a view to hasten the finishing process.

Food Consumed.—Table LXXXIII. gives the amount of hay, ensilage and meal respectively consumed by each steer during the experiment, and the sum of these taken together, also the total of each kind of food and of all the food consumed by the steers of each lot during the experiment.

TABLE LXXXIII.—Food Consumed by the Steers.

	Hay	Ensilage	Meal	Total
Lot No. 1—	Lbs.	Lbs.	Lbs.	Lbs.
(a)	1,536	2,788	1,200	5,524
(b)	1,254	1,745	1,162	4,161
(c)	1,368	2,610	1,206	5,184
Total	4,158	7,143	3,568	14,869
Lot No. 2—				
(a)	1,075	2,620	1,462	5,157
(b)	1,208	2,678	1,463	5,349
(c)	1,251	2,683	1,463	5,397
Total	3,534	7,981	4,388	15,903
Lot No. 3—				
(a)	1,227	2,753	1,727	5,707
(b)	1,332	1,483	1,709	4,474
(c)	1,001	2,668	1,710	5,379
Total	3,560	6,854	5,146	15,560

The steers in lot 2 consumed more fodder, that is to say, hay and ensilage, than those in lot 1. But for the capricious appetite of the steer (b) in lot 1, however, the steers in the latter lot would have consumed more than those in either of the other lots. This experiment, like those preceding it, similar in character, confirms the view that increase in the quantity of meal fed does tend to decrease the consumption in fodder, but not to the extent of making the food ration equally dear.

Table LXXXIV. gives the amount of each kind of food consumed daily by the steers in the different lots, the average amount of the same, and the total daily consumption of food by each individual animal.

TABLE LXXXIV.—Daily Consumption of Food by the Steers.

	Hay	Ensilage	Meal	Total
Lot No. 1—	Lbs.	Lbs.	Lbs.	Lbs.
(a)	11.78	21.28	9.16	42.17
(b)	9.57	18.32	8.87	31.70
(c)	10.44	19.92	9.21	39.57
Average	10.58	18.17	9.08	37.81
Lot No. 2—				
(a)	8.21	20.00	11.16	39.37
(b)	9.22	20.44	11.17	40.83
(c)	9.55	20.48	11.17	41.20
Average	8.99	20.31	11.17	40.47
Lot No. 3—				
(a)	9.37	21.01	13.18	43.56
(b)	10.17	10.94	13.05	34 16
(c)	7.64	20.37	13.05	41.06
Average	9.06	17.44	13.09	39.59

Though the average of meal consumed by the steers in lot 1 was 4.01 pounds per animal per day less than the average consumed by those in lot 3, yet the gains would have probably equaled those made by the latter but for the poor feeding quality of the steer (b) in lot 1. This steer did not take all of the light allowance of meal accorded to him, and to have given more under the circumstances would have certainly affected his gains injuriously. It must be borne in mind, however, that the steer (a) in lot 3 was also an indifferent feeder, but not to nearly the same extent as steer (b) in lot 1.

Weights of the Animals.—Table LXXXV. gives the weight of the individual animals in each lot at the commencement and at the close of the experiment, and the total individual increase in weight. It also gives the totals for each group.

TABLE LXXXV.—Weights of Animals in the Different Lots.

	Weight at the Beginning of the Experiment	Weight at the Close of the Experiment	Total Increase in Weight
Lot No. 1—	Lbs.	Lbs.	Lbs.
(a)	1,215	1,497	282
(b)	1,150	1,292	142
(c)	1,255	1,540	285
Total	3,620	4,329	709
Lot No. 2.—			
(a)	1,078	1,343	265
(b)	1,105	1,320	215
(c)	1,230	1,535	305
Total	3,413	4,198	785
Lot No. 3—			
(a)	1,190	1,498	308
(b)	1,055	1,240	185
(c)	1,220	1,485	265
Total	3,465	4,223	758

Although the steers in lot 1 aggregated 155 pounds more than the steers in lot 3 when the feeding began, and would, therefore, naturally require somewhat larger quantities of food, they gained together but 49 pounds less on a consumption of 40.2 per cent less meal. The close relation between regular consumption of food suitable in kind and at least approximately so in quality is well brought out in the behavior of the steers in lot 2. Throughout the experiment, with the one exception pointed out, they took the food regularly and with avidity, and they came out first in the aggregate gains made.

Table LXXXVI. gives the aggregate daily gains made by the individual animals in the several lots, and also the daily average made by those of each lot.

The daily average increase made was 1.91 pounds. This on the whole is a good average, notwithstanding that two of the steers made very poor gains. And judging by the behavior of the steers in lot 3 these gains would have been

TABLE LXXXVI.—Average Daily Increase Made.

	Lot 1	Lot 2	Lot 3
	Lbs.	Lbs.	Lbs.
(a)	2.15	2.02	2.35
(b)	1.09	1.64	1.41
(c)	2.18	2.33	2.02
Average	1.81	2.00	1.93

more had all the steers been fed meal as heavily as those in lot 3. The evidence rather points to the conclusion that the gains would have been less than they actually proved.

Cost of Food.—Table LXXXVII. gives the cost of each food factor fed to the individual animals in the difierent lots, the total cost of the several food factors fed to each, and the totals of cost in the food fed to the animals of the respective lots.

TABLE LXXXVII.—Cost of Food Consumed.

	Hay.	Ensilage	Meal.	Total.
Lot No. 1—				
(a)	$2.69	$1.74	$4.70	$9.13
(b)	2.19	1.09	4.56	7.83
(c)	2.39	1.63	4.73	8.75
Total	7.27	4.46	13.98	25.71
Lot No. 2—				
(a)	$1.88	$1.64	$5.72	$9.24
(b)	2.11	1.67	5.73	9.51
(c)	2.19	1.68	5.73	9.60
Total	6.18	4.99	17.18	28.35
Lot No. 3—				
(a)	$2.15	$1.72	$6.78	$10.65
(b)	2.33	.90	6.69	9.92
(c)	1.75	1.67	6.71	10.13
Total	6.23	4.29	20.18	30.70

It is interesting to note the relative cost of fodder and meal respectively. With the steers in lot 1 the cost of meal was 19.2 per cent more than that of the hay and ensilage combined. With the steers in lot 3 it was 91.5 per cent greater, and with the steers in all the lots 53.6 per cent

greater. Since meal is usually the more expensive ration, the importance of keeping the relative consumption of meal as low as will be consistent with best results is thus rendered apparent.

Table LXXXVIII. gives the average daily cost of the food consumed by the individual animals in the several lots, and also the daily average cost of the same by lots.

TABLE LXXXVIII.—Average Daily Cost of Food Consumed.

	Lot 1.	Lot 2.	Lot 3.
	Cents	Cents	Cents
(a)	6.97	7.05	8.13
(b)	5.98	7.26	7.57
(c)	6.68	7.33	7.78
Average	6.54	7.21	7.81

It is further interesting to note the increase in the daily cost of the food with the increase in the daily consumption of meal. This fact would lose its significance if a corresponding increase was made in the gains. In this experiment, however, and in the two preceding it, viz.: the one narrated in bulletin No. 44, and the one detailed in the first part of this bulletin, such increase was not secured, hence the conclusion that in fattening cattle, the adjustment of the relation between the respective quantities of fodder and meal to be fed is a matter of great significance to the feeder, and its importance increases with the relative advance in the price of meal.

And just here the caution may be given not to confound low cost of food per day and cheap feeding. These are essentially and radically different. The daily cost of food per day in feeding the steer (b) in lot 1 was less than the daily cost of feeding any of the other steers, and yet by reference to the next table given below, it will be noticed that relatively he was the most costly animal of the nine to fatten, because of the low gains made. The great consideration in feeding cattle is to secure not cheap feeding in the

absolute sense, but rather to secure large relative gains in proportion to the food consumed.

Cost of Increase.—Table LXXXIX. gives the average cost of 100 pounds of increase made by the individual animals in the several lots, and also the average cost of the same by lots.

	Lot 1	Lot 2	Lot 3
(a)	$3.24	$3.49	$3.46
(b)	5.51	4.42	5.36
(c)	3.07	3.15	3.82
Average	3.94	3.69	4.21

In every instance the cost of making 100 pounds of increase was less than the price for which it was sold. The cheapest gain was made by steer (c) in lot 1. He made 100 pounds of increase for $3.07, the cheapest increase ever obtained by the writer in feeding cattle. The increase with (b), the poor feeding steer in the same lot, cost over 79 per cent more than the increase made by the steer (c). It should also be noticed that the increase made by the steers in lot 3, which were fed meal in the largest quantities, cost the most.

Profit Made.—Table XC. gives: 1, the value of the steers in each lot when the experiment began; 2, the cost of the food fed; 3, the total outlay; 4, the value when the experiment closed, and 5, the profit made. The totals in each instance are also given.

TABLE XC.—Value and Profit Made During the Experiment.

	Lot 1	Lot 2	Lot 3	Totals
Value on December 7th, 1896, when the experiment began	$113.31	$106.83	$108.45	$328.59
Cost of food	25.71	28.35	30.70	84.76
Total cost	$139.02	$135.18	$139.15	$413.35
Value on April 17th, 1897, when the experiment closed	200.22	194.16	195.31	589.69
Profit	$61.20	$58.98	$56.16	$176.34

The average profit on each steer in the experiment was $19.59. In this computation no allowance is made for shrink, nor should it be unless the steers had been made to enter the experiment on shrunk weights. But the net individual profit, given later, will not of course be so much, since in getting it the shrink must be deducted. While the greatest profit arose from feeding the steers in lot 1, this did not arise wholly from the returns they made in proportion to the food fed—the steers in lot 2 made a rather better return for the same—some of it is due to the greater original weight which they had when they went into the experiment, and to the increased value on that greater weight made by the feeding. But for the bad feeding quality of the steer (b) however, the profit from the steers in lot 1 would have been considerably increased.

Table XCI. gives the value of the food fed during the experiment, the value of the increase made, and the profit from the said increase.

TABLE XCI.—Profit from the Increase Made During the Experiment.

	Value of Food Fed	Value of Increase in Weight	Profit on the Increase in Weight
Lot 1	$25.71	$32.79	$7.08
Lot 2	28.35	35.06	7.96
Lot 3	30.70	36.31	4.36
Totals	$84 76	$104.16	$19.40

The profit thus made on the increased weight was certainly a handsome one. It was $2.16 on each animal from a period of feeding which covered 131 days. When such a result can be obtained, the judicious feeding of cattle cannot fail to be greatly renumerative. When cattle are being fattened in the Eastern States, the increase made during the fattening period usually costs considerably more than it is worth, because of the high relative price of the foods fed.

Disposal of the Steers.—The steers were sold to Peter Van Hoven, of New Brighton, Minn. The price paid was

Fig. 203—Typical Range Steer When Finished.

$4.62½ per 100 pounds, with a shrink of 4 per cent. They were in turn disposed of by Mr. Van Hoven to the retail trade of the Twin Cities. One chief object sought by Col. W. M. Liggett, the Director, in thus selling when possible in the home market, is to disabuse the idea, too deeply rooted in the minds of many, that the best quality of meat must be brought from without the state. Until recent years much of the best meat used in the Twin Cities was brought in from Chicago, Kansas City and Omaha.

Financial Statement.--Cash received for 9 steers on April 17, 1897, shrunk weight, 12,240 pounds @ $4.62½ per 100 pounds $566.10

Value of 9 steers on December 8th, 1896, on the basis of cost $328.59

Cost of food 84.76

Total outlay 413.35

Total net profit $152.75

Net profit on one steer 16.97

Observations.—1. The food being charged at market values, was charged at a rate at least something over the cost of production. But too much must not be made of this, since the price of food was low in all the lines fed.

2. The weighing of the steers so frequently would, to some extent, hinder their progress, as they were so wild as to resent such handling.

3. The daily calls of visitors would also tend to hold down the gains. Due allowance should be made for this disturbing factor in all experimental feeding that is thus accessible to the public. Its influence in arresting progress increases with the increasing wildness and nervousness of the animals that are being fattened.

4. In response to a request from the Director the purchaser put a valuation upon the individual steers. The values put upon them were as follows: Nos. 7, 8 and 2 were valued at 5 cents per pound; 3, 1 and 6 at 4½ cents; and 5, 4 and 9 at 4 cents. They are placed in the order of finish and excellence which they possessed, and it is worthy of note that the light fed steer (c) is given first place in the valuations. He was rather the heaviest steer in the experiment when it began, and he maintained this position notwithstanding the lightness of the ration. The steers placed second and third respectively were fed an intermediate ration. Too much however must not be made of this valuation in the absence of block tests.

IMPORTANT FACTS SUMMARIZED.

Values.—

1. Value per 100 pounds on the basis of cost when the experiment began, December 8th, 1896.....$3.13
2. Value per 100 pounds on the basis of receipts April 17th, 1897, when the steers were sold..... 4.62½
3. Advance in value per 100 pounds..... 1.49½

Weights.

	Lbs.
1. Average weight of the steers in lot 1, when the experiment began, December 8th, 1896	1,207
2. Average weight of the steers in lot 2 at the same date	1,138
3. Average weight of the steers in lot 3 at the same date	1,155
4. Average weight of one steer in all the lots at the same date	1,167
5. Average weight of the steers in lot 1 at the close of the feeding, April 17th, 1897	1,443
6. Average weight of the steers in lot 2 at the same date	1,399
7. Average weight of the steers in lot 3 at the same date	1,408
8. Average weight of one steer in all the lots at the same date	1,417

Increase in Weight—

1. Total increase in weight made by the steers in lot 1 during the experiment	709
2. Total increase in weight made by the steers in lot 2 during the same period	785
3. Total increase in weight made by the steers in lot 3 during the same period	758
4. Average increase per day made by the steers in lot 1 during the experiment	1.81
5. Average increase per day made by the steers in lot 2 during the same period	2.00
6. Average increase per day made by the steers in lot 3 during the same period	1.93

Food Consumed.—

1. Average amount of meal consumed per day by the steers in lot 1 during the experiment	9.08
2. Average amount of meal consumed by the steers in lot 2 during the same period	11.17

	Lbs.
3. Average amount of meal consumed by the steers in lot 3 during the same period	13.09
Cost of Food—	Cents
1. Average cost of food per day with the steers in lot 1	6.54
2. Average cost of food per day with the steers in lot 2	7.21
3. Average cost of food per day with the steers in lot 3	7.81
Cost of Increase—	
1. Average cost of making 100 pounds of increase with the steers in lot 1	$3.94
2. Average cost of making 100 pounds of increase with the steers in lot 2	3.69
3. Average cost of making 100 pounds of increase with the steers in lot 3	4.21
Increase in Value—	
1. Average value of each steer without shrink on the basis of cost when the experiment began, December 7th, 1896	36.51
2. Average value of each steer without shrink when the experiment closed, April 17th, 1897	65.52
3. Average advance in value, from feeding for 131 days	29.01
Profit.—	
1. Net profit on the steers in lot 1	53.20
2. Net profit on the steers in lot 2	51.21
3. Net profit on the steers in lot 3	48.34
4. Average net profit on each steer	16.97
5. Net profit on the nine steers fed	152.75

CONCLUSIONS.

The following are among the more important of the conclusions that may be drawn from this experiment:

1. That cattle averaging about 1200 pounds when put under experiment can be brought to a good finish and in a reasonable time, on a daily allowance of meal averaging not more than nine pounds per day, with the adjuncts fed in this experiment, and at a less cost than if larger quantities of meal were fed.

2. That cattle which are being fattened will consume quantities of grain in excess of those which give the best return and without getting "off their feed."

3. That twice in this experiment the animals which produced the most profit were those which consumed the largest relative quantities of hay, hence the relation between the proportions of fodder and meal fed should receive careful attention.

4. That since cattle that are being fattened in the feed lots of the west are usually fed much larger quantities of meal or grain than were given to the steers in the experiment, the conclusion would seem to be legitimate that much of the meal or grain fed is worse than wasted.

5. That under the conditions of the experiment beef can be produced as low as $3.07 per 100 pounds, and at an average cost of $3.81 per 100 pounds.

6. That range steers, fed under what may be termed average farm conditions, can be made to yield a substantial profit when judiciously bought, fed and sold.

IMPORTANT FACTS SUMMARIZED FROM THREE EXPERIMENTS.

As the experiment narrated above is the third conducted during successive years at our station, on substantially the same lines, a summary of the results of the three is now given. The first of these is detailed in Bulletin No. 44, and

the second and third in this bulletin. These findings ought to be much more valuable than those obtained from a single experiment.

Values—

1. Average value per 100 pounds on the basis of cost when the experiment began	$3.44
2. Average price paid per 100 pounds for the steers when sold	4.66
3. Average advance in value per 100 pounds between the cost price and the selling price	1.22

Weights—

	Lbs.
1. Average weight of the steers in lots 1 when put upon experiment	1,048
2. Average weight of the steers in lots 2 at the same period	1,045
3. Average weight of the steers in lots 3 at the same period	1,028
4. Average weight of all the steers when put upon experiment	1,040

Daily Gains—

1. Average daily gains made by the steers in lots 1..	1.78
2. Average daily gains made by the steers in lots 2..	1.86
3. Average daily gains made by the steers in lots 3..	1.84
4. Average daily gains made by the steers in all the lots	1.83

Food Consumed—

1. Average of food consumed per day by the steers in lots 1	38.86
2. Average of food consumed per day by the steers in lots 2	40.74
3. Average of food consumed per day by the steers in lots 3	39.02
4. Average of food consumed per day by the steers in all the lots	39.54

Meal Consumed.—

1. Average amount of meal consumed per day by the steers in lots 1..... 8.23
2. Average amount of meal consumed per day by the steers in lots 2..... 10.23
3. Average amount of meal consumed per day by the steers in lots 3..... 12.02
4. Average amount of meal consumed per day by the steers in all the lots..... 10.16

Cost of Food.—

	Cents.
1. Average cost of food per day for the steers in lots 1.....	7.57
2. Average cost of food per day for the steers in lots 2.....	8.48
3. Average cost of food per day for the steers in lots 3.....	9.03
4. Average cost of food per day by the steers in all the lots.....	8.36

Cost of Increase.—

1. Average cost of making 100 pounds of increase with the steers in lots 1.....	$4.34
2. Average cost of making 100 pounds of increase with the steers in lots 2.....	4.59
3. Average cost of making 100 pounds of increase with the steers in lots 3.....	4.92
4. Average cost of making 100 pounds of increase with the steers in all the lots.....	4.62

Profit Without Shrink.—

1. Average profit from feeding the steers in lots 1, without shrink.....	$13.70
2. Average profit from feeding the steers in lots 2, without shrink.....	12.83
3. Average profit from feeding the steers in lots 3, without shrink.....	11.75

4. Average profit from feeding all the steers, without shrink..... $12.76
5. Aggregate profit from feeding 27 steers, without shrink..... 344.49

Net Profit.—

1. Average net profit on each steer in lots 1..... 11.29
2. Average net profit on each steer in lots 2..... 10.41
3. Average net profit on each steer in lots 3..... 9.36
4. Average net profit on each steer in all the lots..... 10.35
5. Aggregate net profit on the 27 steers fed..... 279.45

Observations.—1. The average period during which the steers in the three experiments were fed was 140 days. This is a longer time than is customary to feed in western feed lots, but it is not too long to enable the feeder to put a fine finish on the animals.

2. The advance in value of the cost price over the selling price, viz., $1.22, was not large, yet notwithstanding good average profits were realized as has been shown above. These were made possible through the low price of the foods fed. With foods at normal prices the buyer should aim to have $1.50 per 100 pounds between the buying price and the selling price in order to make a sure and substantial profit.

3. The average daily gains made by the steers of the several lots were not far from uniform, notwithstanding the difference in the quantities of meal fed. But for the poor feeding of one of the light-fed steers in the third experiment, the average daily gains made by the light, intermediate and heavy-fed steers would have been almost exactly equal, hence, feeding meal beyond a certain proportion would not seem to give additional increase in weight.

4. The uniformity in the consumption of food, weight considered, is also markedly noticeable. It did not vary on an average 2 pounds per day with the several lots taken together that were fed different quantities of meal. In other

words, the increase in the quantities of meal fed did not result in a decrease in the consumption of fodder to the extent expected.

5. The wonderfully low cost of the food fed should not be overlooked. The average cost of feeding one steer per day in the three experiments was but 8.36 cents. The average cost of feeding one steer in Ontario in three experiments conducted by the writer and ending with 1892, was 17.59 cents, as previously stated in Section No. 1 of this bulletin. The Ontario steers were somewhat heavier, but the contrast in the weights was not anything like so great as the contrast in the daily cost of feeding.

6. The low cost of the increase per 100 pounds is also noteworthy. With the steers in all the lots it was $4.62, while the average price for which it was sold was $4.66 per 100 pounds. During the three years of feeding, therefore, the cost of the increase was less than it sold for. In but few countries of the world could this be accomplished with food charged at market values.

7. It will be observed that the average profit made is first stated without shrink being considered, and throughout each experiment the profit is thus calculated. The reason for so stating it lies in the fact that the steers entered the experiment on unshrunk weights, and to take them out of it otherwise would not show in all its features the work accomplished. If the animals were made to enter the experiment on shrunk weights, sundry complications would arise that would render much more complex the statement of certain resultant facts. The net profit is of course the actual profit.

8. The net profit on each of the steers in lots 1 was $1.93 more than on each of the steers in lots 3. It was $1.41 per animal more than the average profit from each of the steers in lots 2 and 3 combined, and in each of the three experiments was the profit greatest on the steers fed the light meal ration. It is fair to infer then that had the steers in

these lots been fed as the steers in lots 1, $25.38 additional would have been added to the net profit on the 18 steers in lots 2 and 3. And it should also be borne in mind that the dearer relatively the price of grain, the greater will the contrast be between feeding meal or grain in moderate or in large quantities.

9. The average quantity of meal fed per day in securing the largest profit was only 8.23 pounds. To this must be added some corn which the ensilage contained. The average amount of ensilage consumed per day throughout the feeding was a little more than 21 pounds and it contained a moderate amount of corn, but how much cannot be stated. In any event it would not increase the meal fed daily to those steers to very much beyond 10 pounds. The writer cannot but conclude, therefore, that, in western feed lots, much grain is oftentimes fed to no purpose, since from 25 to 30 pounds of shelled corn are frequently fed per day to one cattle beast and to one pig that feeds upon its droppings.

FATTENING LAMBS AND WETHERS IN WINTER.

THOMAS SHAW.

This Bulletin contains five experiments. They relate to the following subjects, viz.: 1. Fattening home-grown lambs; 2. Fattening home-grown lambs; 3. Potatoes and field roots as food factors in fattening lambs; 4. Fattening range wethers, and, 5. Fattening range wethers. They were conducted during the winters of 1896 and '97, and '97 and '98.

FATTENING HOME-GROWN LAMBS.

SECTION NO. 1.

In the Autumn of 1896, 120 lambs were put under experiment as described in Bulletin No. 57, section No. 2. These lambs were from the range and they were being fed for the market. When the experiment began in November of that year, a small bunch of lambs were on hand that had been grown on the station farm. They were well-developed lambs for their respective ages, but only in store condition. They were grown almost exclusively on summer forage that had been sown that same season. During the previous winter there had been no little controversy with certain of the Twin City dealers as to whether it were possible to bring well-grown lambs to a high degree of finish without overloading them with fat. The writer had taken the stand that it was easily possible to bring lambs to the most perfect finish and yet have the meat of the highest quality for the table; that it was simply a matter of judicious selection of foods and of careful feeding. Not a few of those, however, engaged in handling finished stock contended otherwise. They claimed that very high finish meant an undue proportion of tallow. It was thought best, there-

fore to put these lambs under experiment in the hope of throwing some further light upon this question. It was also thought that some knowledge would be gleaned by feeding them simultaneously with the range lambs. But any such comparisons that may be made in the bulletin must not be taken as final, since the range lambs were not fed on exactly the same food ration.

Time Consumed by the Experiment.—The preparatory feeding began November 9th, 1896, and covered a period of 14 days. The experiment proper began November 23d and ended March 15th, 1897. It thus covered a period of 112 days, or 16 weeks. The whole period of feeding was 126 days, or 18 weeks, an unusually long period to occupy in finishing lambs. Shortly after the experiment closed, the lambs were disposed of as described elsewhere.

Objects Sought in the Experiment.—Prominent among these were the following: 1, to feed the lambs upon a diet that would bring them to a high finish and that would at the same time produce an excellent quality of meat; 2, to ascertain the effect of such a diet upon development during a prolonged period of feeding, and, 3, to test the suitability of lambs grown on summer forage other than grass for being fattened. The secondary objects sought information: 1, as to the behavior of the lambs in comparison with the range lambs fed simultaneously, and, 2, as to the monthly gains which the lambs would make, the food consumed in making these gains and the cost of the same.

The Animals Used.—Ten lambs were fed, all of which were wethers, and all of them were grown on the farm. They came to hand during March, and they had been grown almost entirely on summer forage other than grass. On this forage they had grazed with their dams from about May 1st until November 1st. No grain had been given to them or their dams during the greater portion of the season of pasturage. The foods on which they fed comprised winter rye, peas and oats, corn, sorghum, rape and cabbage. They

were good, thrifty, well-developed lambs. In breeding, they were from a pure Dorset sire and common grade ewes. The dams possessed considerable Merino blood, but the major portion of them had more or less of Down blood. In form, they were fairly blocky in type, but had something of that upstanding appearance which characterizes the Dorsets. And in quality they were good.

Conditions Governing the Experiment.—The lambs were fed under cover, but they had access to a yard at will, except in time of storms. The shed room was 9x12 feet and the yard room 18x28 feet. The yard was on the south side of the building, a matter of no little importance in feeding lambs. They were weighed singly at the commencement of the experiment and every week thereafter, and water and salt were kept on hand. The yards were kept nicely bedded, an important factor in feeding lambs, though too frequently neglected.

Food and Feeding.—The grain fed to the lambs was composed of oats, bran, barley and oilcake, in the proportions of 3, 3, 3 and 1 parts respectively by weight. They were given native hay, and of a poor quality, because of its over-maturity when cut and over-curing before being stored. They were also fed roots, consisting of mangels and carrots. The proportions of these fed were about equal. It will be observed that the ration, taken as a whole, might be termed nitrogenous rather than carbonaceous. The grain was fed unground and the hay uncut. The roots were sliced, and were fed but once a day. The other food was given in two feeds. It was the aim in feeding grain and hay to give the lambs all the food that they would eat up clean, and in feeding roots to give them what may be termed a liberal allowance.

Estimated Value of the Food.—The food was charged at the average market values in the state. These were of course only estimates, but they were close approximations to the actual prices paid. The values were as follows:

Bran, per ton	$6.50
Oilcake, per ton	14.00
Corn, per bushel of 56 pounds	.18
Barley, per bushel of 48 pounds	.16
Oats, per bushel of 32 pounds	.14
Native Hay, per ton	3.00
Roots, per bushel of 50 pounds	.04½
Or, per 100 pounds	.09

These valuations are not far from the actual prices paid. The hay cost the station more than is charged for it, but the bran, on the other hand, which is charged at $6.50 per ton, was bought at $4.50 per ton.

Food Consumed.—Table XCII. gives the aggregate amounts of the various food factors consumed during the experiment proper, the average amounts of the same, and the average amounts consumed by one animal per day.

TABLE XCII.—Food Consumed.

	Aggregates of Food Consumed	Averages of Food Consumed	Average Consumption per Animal per Day
	Lbs.	Lbs.	Lbs.
Grain	2,548	254.8	2.28
Hay	1,038	103.8	.93
Roots	2,108	210.8	1.88
Totals	5,694	569.4	5.09

The average of food consumed per day by the range lambs that were being simultaneously fed was only 2.43 pounds, but no roots were fed to them. This, along with the much smaller size of the lambs, largely accounts for the difference. But it does not perhaps wholly account for it. The lambs in this experiment consumed relatively more hay than the range lambs. With the former, the consumption of hay in proportion to that of the grain was more than 40 per cent.; with the latter, it was a little less than 23 per cent. The explanation is problematical, but it would seem to be true that feeding upon roots inclines the animals to

which they are fed to consume more hay than they otherwise would. If this be true, the gain thus secured is important, as bulky foods are usually the less costly.

During the preparatory feeding the lambs consumed 247 pounds of grain, 208 pounds of hay, and 204 pounds of roots, or a total of 659 pounds. The grand total of food consumed during the whole feeding period was 6,353 pounds.

Value of Food Consumed.—The cost of the various items of food fed during the experiment proper was as follows:

Oats	$3.33	
Bran	2.49	
Barley	2.55	
Oil Cake	1.78	
Total cost of grain		$10.15
Hay		1.56
Roots		1.90
Total		$13.61

Here again attention may be called to the high relative cost of the grain portion of the ration, and also to the high relative cost of the oats in proportion to that of the other grains. And yet it is very questionable if the results would have proved so satisfactory without feeding some oats.

The value of the food consumed in the preparatory feeding was	$1.47
The total value of the food consumed in the entire experiment, 126 days, was	15.08
The value of the food consumed, per animal, during the experiment proper was	1.36
The value of the food consumed, per animal, during the entire experiment was	1.51

Weights of the Lambs.—The following is a synopsis of the weights and gains made by the lambs during the experiment proper, and also during the entire period of feeding:

	Lbs.
Aggregate weights on Nov. 9th, 1896, when the preparatory feeding began	900
Aggregate weights on Nov. 23d, when the experiment proper began	932
Aggregate weights on March 16th, 1897, when the experiment closed	1,342
Aggregate shrunk weights on March 16th, with a shrink of 4 per cent	1,288
Aggregate increase in weight from feeding for 112 days, or during the experiment proper	410
Aggregate increase in weight from feeding for 126 days, or during the entire feeding period	442
Average weight when the preparatory experiment began	90
Average weight when the experiment proper began	93.3
Average weight at the close of the feeding period	134.2
Average increase in weight during the experiment proper (112 days)	41.0
Average increase in weight during the entire period of feeding (126 days)	44.2
Average increase per animal per month of 30 days during the experiment proper	11.0
Average increase per month during the entire feeding period	10.5
Average increase per month of range lambs fed simultaneously for 77 days, but on a ration somewhat different	7.70

The gains thus made were remarkably good. But the high average of the gains is even less a feature of the experiment than their continuity. The period of feeding was a full month longer than it is usual to feed lambs when finishing them, and yet the gains made during its closing weeks

were quite as good as those made at any previous period of the feeding. The prolonged character of the good gains is doubtless chiefly due to the somewhat nitrogenous character of the ration fed, but it was also due to some extent to the inherent goodness of the lambs. Mr. G. Craig, the feeder, gave it as his opinion that in all his experience he never fed a lot of lambs which did so well.

Disposal of the Lambs.—Seven of the ten lambs were sold by Col. W. M. Liggett, the director of the station, to E. M. Prouty & Co., of South St. Paul. Through the wholesale trade of W. E. McCormick they ultimately found their way into the retail markets of St. Paul. The price paid for them was $5.50 per 100 pounds, live weight, with a shrink of 4 per cent. The price received for the range lambs, fed simultaneously and bought by the same buyer and at the same time, was $4.87½ per 100 pounds. At the commencement of the feeding period the lambs were valued at $3.50 per 100 pounds, which was the top price paid for stock lambs at the time. The range lambs fed simultaneously were valued at $3.37 on the basis of cost when put under experiment. The advance in value on the former therefore during the feeding period was $2.00 per 100 pounds, and on the latter it was $1.50.

One of the lambs was presented to the Commercial club, in St. Paul, and was served at a luncheon given by the club at which several of the leading citizens of Minnesota were present. The testimony was unanimous in favor of the high excellence of the mutton. Notwithstanding its high finish, the proportion of the lean to the fat was unusually large, and the blending or intermingling of the fat and lean was simply perfect. The two remaining lambs were slaughtered and found their way to the tables of distinguished citizens of the state. To give even a synopsis of the compliments paid to the high character of the meat from so many quarters would be tedious. As the lambs were disposed of at practically the same time, in the financial com-

putation they will all be valued on the basis of the price received for the lambs actually sold.

Financial Statement.—Value of 10 lambs, shrunk weight (1,288 pounds), when sold March 16, 1897, @ $5.50 per 100 pounds		$70.84
Value of 10 lambs (900 pounds), when the feeding began, November 9th, 1896	$31.50	
Total cost of food	15.08	
Total		46.58
Total net profit		$24.26
Total net profit on one lamb		2.43

Observations.—1. The total net profit from feeding the range lambs simultaneously, but for a period of 77 days only, was but $0.86 per lamb. But too much must not be made of this comparison, as the home-grown lambs were fed on a different ration.

2. It should be borne in mind that the food was charged at market values, which are usually in excess of the cost of production. To charge it thus, therefore, is against the experiment.

3. The cost of bedding, labor and interest on the investment are supposed to be offset by the value of the manure.

IMPORTANT FACTS SUMMARIZED.

Value per 100 pounds—

1.	Estimated value of the lambs per 100 pounds at the beginning of the feeding period, Nov. 9th, 1896.	$3.50
2.	Value per 100 pounds on the basis of actual receipts when sold, March 16th, 1897	5.50
3.	Advance per 100 pounds in value during the period of feeding	2.00

Weights—

	Lbs.
1. Average weight of each lamb when the experiment began, Nov. 9th, 1896	90
2. Average weight of each lamb when the experiment proper began, Nov. 16th, 1896	93.3
3. Average weight of each lamb at the close of the experiment, March 16th, 1897	134.2

Increase in Weight—

1. Average increase in weight per lamb during the experiment proper (112 days)	41.0
2. Average increase in weight per lamb during the entire period of feeding (126 days)	44.2
3. Average increase per animal per month of 30 days during the experiment proper	11.0
4. Average increase per animal per month of 30 days during the entire period of feeding	10.5

Food Consumed—

1. Average amount of grain consumed per day per lamb during the experiment proper	2.28
2. Average amount of hay consumed per day per lamb during the experiment proper	.93
3. Average amount of roots consumed per day per lamb during the experiment proper	1.88
4. Total average amount of food consumed per day per lamb during the experiment proper	5.09

Cost of Increase—

1. Cost of making 100 pounds of increase during the experiment proper (112 days)	$3.32
2. Cost of making 100 pounds of increase during the whole period of feeding	3.41

Value per Lamb—

1. Average value of each lamb when the feeding began, Nov. 9th, 1896	3.15
2. Average value of each lamb at the close of the experiment, March 16th, 1897, on the basis of shrunk weights	7.08

3. Average advance of each lamb in value during the whole period of feeding..... $3.93

Profit—

1. Total profit from feeding 10 lambs for 126 days... 24.26
2. Total profit from feeding 1 lamb for 126 days..... 2.43

CONCLUSIONS.

1. That it is possible to so fatten lambs that the finish will be of a high order without unduly loading them with fat.

2. That the ration used in the experiment, viz: bran, oats, barley and oilcake, in the proportion of 3, 3, 3 and 1 parts respectively, with hay and roots, is well adapted to the production of such meat.

3. That such a diet is eminently adapted to the production of large gains, since during the experiment proper, it produced monthly 11 pounds of increase.

4. That such a ration is also eminently adapted to sustaining the ratio of increase during a long feeding period, since the lambs gained about as much during the last part of the feeding period as during the first part thereof.

5. That it is admirably adapted to the cheap production of mutton, since 100 pounds of increase was made during the entire period of feeding at a cost of but $3.41.

6. That because of the all round excellence of the results obtained, the growing of lambs on forage other than grass pastures, leaves them in a fair condition for being successfully fattened.

FATTENING HOME-GROWN LAMBS.

SECTION NO. 2.

THOMAS SHAW.

The lambs fed in this experiment, as described below, were grown at our station. It so happened that they were on hand in the autumn of 1897, when the Montana lambs brought in from the range were put under experiment. As it was necessary to fatten them before they went to the market, it was decided that this should be done under conditions similar to those under which one of the range lots were fed. The comparison, however, was hardly fair to the home grown lambs. The Montana lambs were reasonably good representatives of range lambs, but the home grown lambs as described below, were under the average for lambs of that class. While too much stress is not to be laid upon the results of this little experiment, it is hoped that some useful facts may be gleaned from it.

Time Covered by the Experiment.—The experiment began Nov. 15th, 1897, and ended March 7th, 1898, thus covering a period of 112 days. Five days later, that is to say, on March 12th, the lambs were sold and sent to the block. The whole period of feeding therefore covered 117 days. They were thus virtually fed simultaneously with the Montana lambs as described in Bulletin No. 57, section 3, and went to the same buyer, the same market and at the same date.

The Objects of the Experiment —The chief object sought was to compare the feeding qualities of very ordinary home grown lambs with lambs of fair quality grown on the range. But other issues in the comparison were also taken into the account, as, for instance, the increase in weight that was

made, the cost of food used in making it, the consumption of food and the relative profit in the transaction.

The Animals Selected.—Nine lambs were used in the experiment and with one exception they were wethers. They were the remnant of the lambs dropped at the station in the spring of 1897, after the best had been sold early in the season or had been selected later for breeding uses. To put it boldly they were the culls of the flock, and yet they were hardly deserving of such a designation, as they were not really culls, but they were under the average of well grown farm lambs. Nearly all of them were from a Dorset sire and grade ewes, but some of them were possessed of not a little of Down blood. Three of them had fairly good mutton form, the others were a little rangy, high up from the ground, and were lacking in width.

Conditions Governing the Experiment.—The lambs were fed in an apartment of the main sheep shed and had access at will, save in stormy weather, to a yard on the south side of the shed. The dimensions of the apartment were 9x12 feet, and those of the yard 18x28 feet, and both were kept well littered. They were weighed singly at the first and every two weeks thereafter, and the weights were duly recorded. They were given all the food of each kind that they would eat up clean and with a relish, and no more. They had access virtually to water at will during the day and had also access to common salt. The former was kept in a pail in the pen, and the latter in a box.

Food and Feeding.—These lambs were pitted against those of lot 2, described in section 3 of Bulletin No. 57, and were therefore fed on the same kinds of food. The grain portion consisted of oilcake, bran, barley and oats. It was given in the proportions of 1, 2, 3 and 4 parts respectively by weight. The hay was clover and timothy, the former predominating, and they were also given sorghum ensilage daily from December 28th, that is to say, during the last 70 days of the experiment proper. The food was fed in two

feeds daily, morning and evening, except the ensilage, which was given only in the evening. The barley and oats were fed whole, and the hay was given uncut.

Estimated Value of the Food.—The food was charged at the average market values of the same throughout the state as nearly as these could be ascertained. On this basis the respective values were as follows:

Oilcake, per ton	$22.00
Wheat bran, per ton	7.50
Barley, per bushel of 48 pounds	.20
Oats, per bushel of 32 pounds	.17
Hay, per ton	4.00
Ensilage, per ton	1.20

All the food fed was of very fair quality.

Food Consumed.—Table XCIII. gives the total of each kind of food consumed by the 9 lambs throughout the experiment proper, and the amount consumed daily by the same and by each lamb on an average.

TABLE XCIII.—Food Consumed.

	Total Food Consumed	Total Food Consumed per Day	Total Food Consumed by one Lamb per Day
	Lbs.	Lbs.	Lbs.
Grain	1,979	17.66	1.96
Hay	1,101	9 83	1.09
Ensilage	405	5.78	.64
Totals	3,485	33.27	3.69

The range lambs fed under similar conditions consumed daily the following amounts of food:

	Lbs.
Grain	1.86
Hay	.83
Ensilage	.55
Total	3.24

To make the consumption of food equal in the two lots pitted against each other, the range lambs must needs have eaten 3.16 pounds daily. The home-bred lambs therefore consumed less food in proportion to their live weight, notwithstanding their greater age.

Cost of Food Consumed.—The food fed during the experiment proper cost as follows:

Grain	$10.34
Hay	2.20
Ensilage	.24
Total	$12.78

The average cost of the food fed to each lamb, therefore, was $1.42, while the average cost of the same fed to each range lamb was $1.30.

Weights of the Lambs.—Table XCIV. gives the aggregate and average weights of the lambs at the beginning of the experiment, Nov. 15th, 1897; at its close, March 7th, 1898; at the date of sale, March 12th, and also the shrunk weights at the date of sale.

TABLE XCIV.—Weights of the Lambs.

	Aggregate Weight	Average Weight
	Lbs.	Lbs.
Weight on November 15th, 1897	653	72.5
Weight on March 7th, 1898	967	107.4
Weight on March 12th	1,000	111.1
Weight (shrunk) on March 12th	950	105.5

The amount of shrinkage called for when the lambs were sold was five per cent.

Gains Made During the Experiment.—The total increase in weight made by the lambs during the experiment proper was 314 pounds. The average increase was 34.9 pounds against 35.3 pounds made by the range lambs. The average increase per month of 30 days was 9.3 pounds against 9.5 pounds made by the range lambs, and it will be observed

that these greater relative gains made by the latter were obtained from a less quantity of food. This may of course be in part accounted for by the younger age of the range lambs. The cost of making 100 pounds of increase in weight during the experiment proper was $4.07 against $3.67 for the range lambs.

Financial Results—At the beginning of the experiment the lambs were valued at $3.41 per 100 pounds. This value was fixed on the basis of the actual cost of the range lambs against which they were pitted in the experiment. They were sold to P. Van Hoven, of New Brighton, Minn., who also bought the range lambs. The price paid for both lots was the same, viz., $5.50 per 100 pounds shrunk weight.

The following is a summary of the financial results:

Value of the lambs at the beginning of the experiment	$22.27	
Value of the food fed	13.50	
Total		35.77
Price received for the lambs when sold		52.25
Total net profit		16.48
Average net profit on each lamb		1.83
Average profit on each range lamb		1.55

The home bred lambs therefore gave a net profit of 28 cents per lamb greater than the range lambs similarly fed. This may seem strange when it is remembered that the range lambs made a somewhat better average increase in weight. The explanation is found in the greater weight of the home-bred lambs at the beginning of the experiment, and the increase in value put upon the original weight by fattening the lambs. And this result is probably the most important fact to be emphasized in the bulletin.

The value of the manure is supposed to offset the cost of labor and of the bedding used, and also the interest on the investment. Whether this estimate is unduly favorable to

the experiment must be judged by each individual in the light of his own conditions. And it ought to be remembered that the food fed was charged at average market values. These values are unfavorable to the experiment since they are usually in excess of the cost of growing foods. Such cost would be the proper basis for valuing the same when fed upon the farm.

IMPORTANT FACTS SUMMARIZED.

This summary is intended to bring out in clear and concise form the essential points of contrast in the behavior of the home-bred and range lambs respectively pitted against each other in the experiment.

	Home-bred Lambs. Lbs.	Range Lambs. Lbs.
Food Consumed—		
Total food consumed per day	3.69	3.24
Weights—		
Average weight at the beginning of the experiment	72.5	61.2
Average weight at the close of the experiment	107.4	98.2
Average increase in weight, 112 days	34.9	35.3
Average increase in weight per month	9.3	9.5
Cost—		
The cost of making 100 pounds of increase	$4.07	$3.67
Values—		
Value per 100 pounds at the beginning of the experiment	4.41	4.41
Value per 100 pounds at the close of the experiment	5.50	5.50
Profit—		
Total net profit per lamb	1.83	1.55

POTATOES AND FIELD ROOTS AS FOOD FACTORS IN FATTENING LAMBS.

SECTION NO. 3.

THOMAS SHAW.

Many sections of Minnesota are peculiarly adapted to the growth of potatoes. In some seasons of the past the crop grown has been so immense that if sold at all it must needs be sold at a very low price. Such was the crop of 1895. During that year acres and acres of potatoes were left undug because the growers could not obtain for them a price that would pay for the cost of handling, and in many instances they had no live stock to feed them to. Others who had some live stock were enabled to feed a certain percentage of the crop. The attention of some of the farmers was therefore called to the feeding value of potatoes. In certain portions of the state, mangels also and sugar beets can be grown in excellent form. It was thought best, therefore, to undertake some experimental work with a view to throw some light as to the merits of potatoes and field roots respectively in feeding lambs.

Time Covered by the Experiment.—The preparatory experiment began November 15th, and covered a period of seven days. The experiment proper began November 22d and ended Feb. 28th. It therefore covered a period of 98 days, or 14 weeks; and the subsequent feeding continued until March 12th following, when the lambs were sent to the block. The whole period of feeding therefore covered 117 days. The lambs were sold to Mr. P. Van Hoven, of Minneapolis, and were finally disposed of in the retail markets of the Twin Cities.

Objects Sought in the Experiment.—The following are chief among the objects sought in the experiment: 1, to

ascertain the value of potatoes, mangels and sugar beets respectively as food factors in fattening lambs, and, 2, to ascertain the outcome from feeding very ordinary range lambs under what may be termed high pressure feeding. Among the secondary obejcts were the following, viz.: To ascertain, 1, the respective amounts of the food fed consumed daily by such lambs; 2, the gains made by them, and, 3, the cost of such gains.

The Animals Used.—The lambs used in the experiment formed part of a carload bought from Wm. B. Shaw, manager of Prospect Ranch, Culbertson, Montana. They were virtually the least valuable of a lot of 300 shipped down from the said ranch after a first choice of 120 had been taken from the lot for experimental feeding, and after a second choice of 100 had been sold. They were the culls of the lot, and yet it would be hardly fair to call them culls as, though small and rather thin, they had considerable breeding in them. The sires were Oxford Downs and the dams grade Merinos, from which the major portion of the wrinkles had been removed. As a matter of course, however, they had not the plump bodies of the lambs previously taken from the lot, nor had they so good a spring of rib.

Conditions Governing the Experiment.—The lambs used in the experiment numbered 36 head. They were divided into three lots of 12 each. Those to which the potatoes were fed will be spoken of as lot No. 1; the lambs to which the mangels were fed will be spoken of as lot No. 2, and those to which the sugar beets were fed as lot No. 3. They were fed in three separate apartments of the piggery adjacent to each other. These were each 8x11 feet, and they opened by means of small doors into yards 8x20 feet each. The yards were located very favorably as they were on the sunny side of the building. It was a real pleasure to see the little fellows lying in the sunshine chewing the cud of contentment in the cold days of winter.

They were weighed when the experiment began and every two weeks thereafter. They had accesss to water and salt at will, as both were kept on hand in the pens.

Food and Feeding.—The grain portion given to the lambs consisted of corn, barley and oilcake, fed in equal parts by weight. The hay consisted of clover and timothy, clover predominating. The grain and hay fed to the lambs in each lot were the same in kind, and, as previously intimated, potatoes were fed to the lambs in lot 1, mangels to those in lot 2, and sugar beets to those in lot 3. The grain was not ground nor was the hay cut, and the potatoes and roots were sliced before being fed. The grain and roots were fed together, and each kind of food was fed twice a day, that is to say, in the morning and in the evening. They were gradually led up to a full ration, and were then given all the food they would eat up clean of each kind.

Estimated Value of the Food.—The food was estimated at the average market values for the same in the state. These were as follows:

Hay, per ton	$4.00
Oilcake, per ton	22.00
Corn, per bushel of 56 pounds	.22
Barley, per bushel of 48 pounds	.20
Potatoes, per bushel of 60 pounds	.20
Mangels, per bushel of 50 pounds	.05
Sugar beets, per bushel of 50 pounds	.05½

In other words, the potatoes were valued at 33 cents per 100 pounds, mangels at 10 cents and sugar beets at 11 cents.

Food Consumed.—Table XCV. gives the amounts of grain, hay and roots, respectively, consumed by the lambs during the 98 days of the experiment proper.

TABLE XCV.—Food Consumed.

	Grain.	Hay.	Roots.	Totals.
	Lbs.	Lbs.	Lbs.	Lbs.
Lot 1	1,705	956	1,484	4,145
Lot 2	1,701	956	1,463	4,120
Lot 3	1,745	959	1,488	4,192
Totals	5,151	2,871	4,435	12,457

The evenness in the consumption of food by the lambs of the different lots is very marked. In the totals, the extreme of difference is only 72 pounds. The lambs in lot 3 consumed a little more grain than the lambs in the other lots, but in the items of hay and roots they were virtually the same.

The totals of food consumed daily by the lambs in the different groups was as follows:

	Lbs.
Lot 1	3.52
Lot 2	3.52
Lot 3	3.57
Average	3.54

As far as food conditions are concerned, it would be scarcely possible to get them more even throughout an experiment than in the present instance.

Value of Food Consumed.—Table XCVI. gives the respective values of the food consumed during the experiment proper, and the total value of the same.

TABLE XCVI.—Value of Food Consumed.

	Grain.	Hay.	Roots.	Totals.
Lot 1	$10.85	$1.91	$4.95	$17.71
Lot 2	10.83	1.91	1.46	14.20
Lot 3	11.11	1.91	1.64	14.66
Totals	$32.79	$5.73	$8.05	$46.57

It will be observed that the cost of food was considerably more with the lambs of lot 1 than with those of the other lots, and it was almost entirely owing to the greater cost of the potatoes as compared with the other roots. The difference amounted to $3.51 as compared with the mangels and $3.05 as compared with the sugar beets.

Profits Made During the Experiment Proper.—Table XCVII. gives, 1, the value of the lambs of each lot at the commencement of the experiment proper; 2, the cost of the food fed during the same; 3, the total value of the lambs, and, 4, the total profit made during the 98 days of the experiment.

TABLE XCVII.—Profit Made.

	Lot 1.	Lot 2.	Lot 3.	Totals.
Value on Nov. 22, 1897.	$20.27	$20.37	$20.27	$60.91
Cost of food	17.71	14.20	14.66	46.57
Total cost	$37.98	$34.57	$34.93	$107.48
Value on Feb. 28, 1898.	48.25	47.40	49.75	145.40
Profit	$10.27	$12.83	$14.82	$37.92

In the above computation the value put upon the lambs was the actual cost, less 25 cents per 100 pounds than the price paid for the whole car load when bought. This deduction was made because the lambs used in the experiment were inferior to the average of those purchased. The value of the lambs therefore, when the experiment proper began, was made up of the following items, viz: 1, the sum paid for the lambs in Montana on the basis of weights, less the deduction stated above; 2, the cost of freight calculated on the basis of weights; and, 3, the cost of pasture and of food prior to the commencement of the experiment proper. The average weight of each lamb when bought was 49.6 pounds. The estimated price in Montana was $2.75 per 100 pounds, hence the average value per lamb was $1.36. The average cost of freight was 21 cents per lamb. The cost of pasture was 5 cents, and the cost of the other food 7½ cents per lamb.

The average cost of each lamb, therefore, when the experiment proper began, was $1.69½. The average cost per 100 pounds was $3.34. At the close of the experiment the lambs were valued at $5.00 per 100 pounds, which was the price actually paid for them on March 12th, a few days subsequent to the close of the experiment.

The total average profit made on one lamb in the respective lots during the experiment proper was as follows:

On each lamb in lot 1	$0.86
On each lamb in lot 2	1.07
On each lamb in lot 3	1.24
Average on each lamb	$1.06

In this computation shrunk weights were of course not considered. It will also be noticed, first, that the less profit made on the lambs in lot 1 arose not from a lack of increase in weight, but rather from the greater relative cost of the potatoes as compared with the other roots fed; and second, that the greater profit made on the lambs in lot 3, as compared with those in lot 2, arose from the superior gains which they made, as will be shown later.

Weights of the Lambs.—Table XCVIII. gives the aggregate weights of the lambs in each lot at the beginning of the preparatory experiment; at the beginning of the experiment proper; at the close of the same; and at the date of shipment, with the totals in each instance.

TABLE XCVIII.—Aggregate Weights.

	Lot 1.	Lot 2.	Lot 3.	Totals.
	Lbs.	Lbs.	Lbs.	Lbs.
Weights on Nov. 15, '97	595	597	595	1,787
Weights on Nov. 22.....	607	610	607	1,824
Weights on Feb. 28, '98	965	948	995	2,908
Weights on March 12....	990	965	1,010	2,965

The evenness of the weights at the beginning of the experiment is a noticeable feature. This fact linked with the

nearly equal consumption of food should add to the value of the experiment.

Table XCIX. gives the average weight of the lambs in each lot when the preparatory experiment began; when the experiment proper began and closed; and the average total increase in weight made by the lambs in each lot during the whole period of feeding.

TABLE XCIX.—Average Weights and Average Gains.

	On Nov. 15, 1897.	On Nov. 22.	On Feb. 28, 1898.	On March 12.	Average Gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot 1.....	49.6	50.6	80.4	82.5	32.9
Lot 2.....	49.8	50.8	79.0	80.4	30.6
Lot 3.....	49.6	50.6	82.9	84.2	34.6

The average gain per month for the lambs during the experiment proper was 9.2 pounds and during the whole period of feeding it was 8.4 pounds. The feeding value of potatoes as a factor in fattening lambs is well sustained in this experiment, as, though the gains were a little behind those obtained from the sugar beets, they were ahead of those obtained from feeding the mangels.

The average cost of making 100 pounds of gain during the experiment proper with the lambs of the different lots, was as follows:

Lot 1	$4.94
Lot 2	4.20
Lot 3	3.78
Average	$4.31

The average gain per month made by the lambs during the experiment proper was 9.2 pounds, against 9.07 pounds made by superior lambs of the same shipment as described in Bulletin No. 57, section 3. The explanation is probably found in the free use made of roots and oil cake in the ration fed

to the former. But the greater cost of the ration must not be lost sight of. While, with the former it cost $4.33 to make an increase of 100 pounds in weight, with the latter it cost only $3.78. The added cost was chiefly owing to the large amount of oil-cake fed to the lambs in the present experiment.

Profit on Increase in Weight During the Experiment Proper.—Table C. gives the cost of food fed to the lambs of each lot during the experiment proper, the value of the increase in weight and the profit on the said increase.

TABLE C.—Profit on Increase in Weight During the Experiment Proper.

	Cost of Food Fed.	Value of Increase in Weight.	Profit on the Increased Weight.
Lot 1	$17.71	$17.90	$0.19
Lot 2	14.20	16.90	2.70
Lot 3	14.66	19.40	4.74

In this experiment also, the profit on the increased weight is considerable, a result which cannot be attained where the prices of food are relatively dear. The high price of the oil cake and potatoes combined almost wiped out the entire profit on the increased gain with the lambs in lot 1.

On February 25, one lamb in lot 2 died. Death was caused by some urinal trouble, but whether this arose from feeding mangels was not clear. This lamb was the next day replaced by another of equal weight. No disturbance therefore was caused in the weights by the death of the lamb, but, as noted below, his value is deducted in the final reckoning. The shrunk weight of this lamb was 85.5 pounds, and his value was $4.28. His pelt was sold for 50 cents. The lambs were sold for 5 cents per pound, with a shrink of 5 per cent. The aggregate shrunk weight was 2,816.7 pounds.

Financial Statement.—A summary of the facts relating to the financial side of the whole transaction is now submitted:

Cash return for 36 lambs delivered at New Brighton, Minn., less the value of the lamb that died		$137.06
Value of 36 lambs in Montana	$48.96	
Freight	7.56	
Pasture	1.80	
Food	53.19	
Total outlay		111.51
Total net profit		$25.55
Average net profit		.71

Observations.—The following observations will now be in order:

1. The value of the lamb that died is not only charged against the experiment, but also the value of the food which he ate. Deducting the value of this food would make the net profit per lamb 74 cents.

2. The value of the manure is supposed to offset the bedding, labor and interest on money invested.

3. The food fed is charged at average market values, which are considerably in excess of the home values for the same.

4. The profit on the superior lambs fed simultaneously, as described in Bulletin No. 57, section 3, was $1.49 per head. This greater profit is chiefly to be accounted for in the cheaper foods fed to the former, and in the advance of 50 cents per hundred for which they were sold. Had the latter been sold for $5.50 per hundred as the former were, they would have netted a profit of $1.10 per head instead of 71 cents.

IMPORTANT FACTS SUMMARIZED.

Values—

1. Price allowed per hundred for the lambs in Montana	$2.75
2. Value per hundred when the preparatory experiment began, November 15th, 1897	3.26

3. Value per hundred when the experiment proper began, November 22d	$3.34
4. Value per hundred, shrunk weight, when the lambs were sent to the block, March 12th, 1898.	5.00
5. Difference per hundred between the cost price, November 15th, 1897, and the selling price, March 12th, 1898	1.74
Freights—	
1. Cost of freight on each lamb in the shipment of 299 lambs from Montana, computed on the basis of weights	23.3
2. Cost of freight on each lamb in the experiment, computed on the basis of weights	21.
3. Cost of freight on a double-deck car from Culbertson, Montana, to St. Paul, 702 miles, with a cargo of 25 wether and 299 lambs	82.10
Weights—	Lbs.
1. Average weight of 299 lambs bought in Montana on reaching the station	55.5
2. Average weight of 36 lambs used in the experiment on reaching the station	49.6
3. Average weight at the close of the experiment proper, February 28th, without shrink	80.8
4. Average weight when sent to the block, March 12th, with a shrink of 5 per cent	78.2
Increase in Weight—	
1. Average increase in the weight of each lamb during the experiment proper	32.7
2. Average increase per month during the experiment proper	9.2
3. Average increase per month during the entire feeding period	8.4
Food Consumed—	
1. Average amount of food consumed per day by each lamb during the experiment proper	3.54

	Lbs.
2. Average amount of grain consumed per day by each lamb during the experiment proper	1.46
3. Average amount of hay consumed	.81
4. Average amount of roots consumed	1.26

Cost of Increase—

1. Average cost of making 100 pounds of increase in weight during the experiment proper	$4.33
2. Average cost of making 100 pounds of increase during the whole period of feeding	4.51

Profits—

1. Average value of each lamb (36) at the beginning of the experiment, November 15th, 1897	1.62
2. Average value of each lamb (35) at the close of the experiment, March 12th, 1898	3.91
3. Average advance in value over the cost made by each lamb during the entire feeding period	2.29
4. Total net profit from feeding 36 lambs	25.55
5. The total net profit from feeding one lamb	.71

CONCLUSIONS.

The following include the more important of the deductions based upon the results of this experiment.

1. That lambs of but indifferent development may be fed at a substantial profit with food and meat at the values named in this experiment.

2. That, in feeding lambs, potatoes compare favorably with mangels and sugar beets in producing increase in weight, but they are more costly food than the roots named.

3. That because of the greater cost of potatoes as compared with mangels and sugar beets, they should not be grown as food for lambs where the latter can be grown successfully.

4. That judging by the results obtained in this one experiment, sugar beets are a more valuable food for fattening lambs than either potatoes or mangels.

FATTENING RANGE WETHERS.

SECTION NO. 4.

THOMAS SHAW.

Prior to 1893 it was not customary to ship lambs from the ranges to the Eastern markets unless where the pastures had been overstocked. The fleece was considered of too much value relatively to justify such shipments. Sheep were usually retained on the range until matured. In some instances wethers were not shipped eastward until four years old, as a result of this mode of managing range stocks, the animals sent to the feed lots were full grown wethers and old ewes, but after the great drop in wool in 1893, the mutton feature of the business began to assume a relative importance which it had never previously possessed. This, along with the depression in the wool trade, led to the wholesale shipment of lambs, many of which were also brought up for the feed lots. In consequence of this change, the question naturally became prominent as to whether the feeding of lambs or wethers was the more profitable. Feeders were divided in their opinions, some of them argued that because of the greater weight of wethers at the time of purchase more money would be made on them through the advance in value on the purchase price per pound. Those who held this view had an extensive following, others contended that the lambs would make gains more cheaply, and that the advance on the purchase price per pound would also be greater. The writer held the latter view, and to throw more light upon it the experiment was undertaken, the details of which are given in this bulletin.

Time Covered by the Experiment.—The preparatory feeding began November 10th, 1896, and lasted for six days. The experiment proper began November 16th and lasted

until February 8th, 1897, thus covering a period of 84 days. The whole period of experimental feeding therefore continued for 91 days. The wethers were not marketed until March 24th following, but the experimental feeding ceased on the date mentioned, that a proper comparison could be instituted between them and the lambs that were fed simultaneously. The experimental feeding of the lambs also terminated on February 8th.

Objects Sought in the Experiment.—The following are chief among the objects sought: 1, to determine the results from feeding range wethers in a contest with range lambs fed on similar foods and under similar conditions; and, 2, to ascertain the relative profit from such feeding. Among the secondary objects were the following, viz.: To ascertain 1, the relative gains made; 2, the relative consumption of food used in making them, and 3, the relative cost of the same.

The Animals Used.—The wethers used in the experiment were 20 in number. They were part of a car load of sheep and lambs bought from Wm. B. Shaw, Manager of Prospect ranch, Culbertson, Montana. Culbertson is on the line of the Great Northern Railroad and is 702 miles west of St. Paul. The shipment was made late in September. In it were 100 wethers and 187 lambs, one deck load of each. They were unloaded in transit at the University State Sub-Experimental station at Crookston. The object was to pasture them there on the abundant pastures at the station farm, and later to finish them at the central station at the Twin Cities. Unusually cold weather for the season soon greatly injured the pastures, hence the major portion of the wethers and lambs were brought down to the station at this place on October 28th, and on November 6th they were put under experiment as previously stated.

In breeding they were essentially grade merino. But few of them had any other tinge than white on the face, many of them had more or less of wrinkles on the neck, and

comparing them with wethers grown in the state, they were a little higher up from the ground. Nevertheless, all of them probably were possessed of more or less of down blood. The lot fed were only a good average among the 100 animals of the shipment. They were one, two and three years old. They cost $3.00 per head in Montana. The freight was 43½ cents each on the basis of weight, and as nearly as could be ascertained the value of food and pasture from the arrival of the animals at Crookston, until put under experiment was 10½ cents per head. On the basis of cost, therefore, they were worth $3.81 per animal when the feeding began November 10th, and $3.87 per animal when the experiment proper began November 16th. The cost per 100 pounds when the former experiment began was $3.37, and when the latter commenced it was $3.31.

Thirty lambs of the same shipment were pitted against the wethers in the contest. On the basis of cost the lambs were worth $1.92 each on November 10th and $2.00 each on November 16th. Their value per 100 pounds on the same basis was $3.37 at the former date and $3.44 at the latter. Both lambs and wethers were grown on the same ranch and sold to the same buyer. The experiment, therefore, was a very fair one. The lambs had a slight advantage probably in breeding.

Conditions Governing the Experiment.—They were fed in an apartment of the shed 18x20 feet and had free access to a yard of similar size. The yard was on the north side of the shed. They had access to water and salt virtually at will. They were weighed singly when first put upon feed and every week thereafter. The shed and yards were kept nicely bedded.

Food and Feeding.—The grain consisted of oil-cake, bran, corn and oats, fed in the proportions of 1, 2, 3 and 4 parts by weight. The hay was native. It had been cut on land unharvested the previous year, and consequently the old and new growths were mixed. This, along with over-

curing made a very unpalatable fodder. No other food was given. The grain was fed whole and the hay uncut. They were given only what they would eat up clean and with a relish. The food was fed in two feeds per day.

Estimated Value of the Food.—The value put upon the food was an estimate, though in reality the estimate is about as much as was actually paid for the food. The estimate aims to give the average market values of the food in the state. These are as follows:

Oilcake, per ton	$14.00
Wheat Bran, per ton	6.50
Corn, per bushel of 56 pounds	.18
Oats, per bushel of 32 pounds	.14
Native hay, per ton	3.00

Food Consumed. — Table CI. gives the aggregate amounts of the food consumed during the experiment proper, the average amount of the same consumed per animal, and the average amount consumed per day per animal.

TABLE CI.—Food Consumed.

	Aggregates of Food Consumed.	Averages of Food Consumed.	Average Consumption per Animal per Day.
	Lbs.	Lbs.	Lbs.
Grain	5,041	252.1	3.00
Hay	1,707	85.4	1.02
Totals	6,748	337.5	4.02

The average consumption of food per day by the range lambs that were fed simultaneously and on similar food was 2.51 pounds per day. In the preparatory feeding 186 pounds of grain were consumed, and 263 pounds of hay. The total consumption of food therefore during the 91 days of feeding was 7,197 pounds.

Value of Food Consumed.—The cost of the various items of food fed during the experiment proper was as follows:

Oilcake	$3.53	
Bran	3.28	
Corn	4.86	
Oats	8.82	
Total cost of grain		$20.49
Hay		2.56
Total		$23.05

In all our experience in feeding, thus far, in Minnesota, oats has been the dear grain food. Whether they could as well be entirely dispensed with in fattening sheep has not been proved, but the relatively dearer price should certainly lead to caution in feeding them.

The value of the food consumed during the preparatory feeding was $1.16, and during the whole experiment $24.21. The cost of feeding one wether therefore for 91 days was $1.21.

Weights of the Wethers.—The following is a synopsis of the weights and gains made by the wethers during the 84 days of feeding of the experiment proper, and also during 91 days while under experiment.

	Lbs.
Aggregate weights on November 10th, 1896, when the preparatory experiment began	2,260
Aggregate weights on November 16th, when the experiment proper began	2,337
Aggregate weights February 8th, when the experiment closed	2,805
Aggregate weight when shrunk 4 per cent	2,693
Aggregate increase for 84 days, or during the experiment proper	468

	Lbs.
Aggregate increase for 91 days, or during the whole period of feeding	565
Average weight November 10th, 1896	113
Average weight November 16th, 1896	116.8
Average weight February 8th, 1897	140.3
Average increase in weight during the experiment proper	23.4
Average increase in weight during the whole period of feeding	27.2
Average increase per month during the experiment proper	8.4
Average increase per month during the entire period of feeding	9.0

It may appear strange that the wethers should gain so much more during the period of 91 days feeding of the whole experiment as compared with the 84 days feeding of the experiment proper. But that simply illustrates the uncertain element in weights. A bunch of animals may weigh so many pounds one day and a few days hence they may weigh more or less. Because of this, conclusions based on very short periods of feeding certain foods may be misleading.

Disposal of the Wethers.—The wethers were not sent to the block when the experiment closed. The feeding continued until March 24th, 1897, but the experiment closed on February 8th, as both the wethers and lambs were then considered ready for the block. The delay in the sale was made by the desire to place them and the lambs also upon a home market. They were valued however at the price paid on March 24th, which was $4.00 per 100 pounds, as the price of meat was, if anything, dearer on February 8th than on March 24th. They were sold to E. M. Prouty & Co., of South St. Paul, and through W. E. McCormick they went to the retail trade.

Financial Statement.—Value of 20 wethers at $4.00 per 100 pounds, shrunk weight, when the experiment closed, February 8th, 1897		$107.72
Value of 20 wethers when the experiment proper began, November 16th, 1896, on the basis of cost	$77.35	
Cost of food	23.05	
Total cost		100.40
Net profit		$7.32
Net profit on one wether		.36
Net profit on one lamb as pitted against the wethers		.85

Observations.—1. The food was charged at market values. Although these were very low they are probably more than the home values, and in so far as they exceed home values they tell against the net profit in the experiment.

2. The value of the manure is supposed to offset the cost of bedding, labor and interest on the investment.

3. On the whole the experiment was a very fair one as previously intimated, as the conditions were even and uniform. The animals in both lots maintained good health to the close of the experiment. Both wethers and lambs went into the experiment at the same date and at the same cost per 100 pounds. Both were disposed of at the same time and to the same buyer. Notwithstanding, the net profit on the lambs, per animal, from 84 days' feeding, was 85 cents, while on the wethers it was but 36 cents. This result was the outcome of the better gains made by the lambs from the food fed, and also of a greater advance in the value per pound during the period of feeding. These points are clearly brought out in the summarized statement which follows.

IMPORTANT FACTS SUMMARIZED.

Values.—

1.	Estimated price per 100 pounds paid for the wethers in Montana on the basis of unshrunk weights	$2.83
2.	Value per 100 pounds when the experiment began	3.37
3.	Value per 100 pounds when the experiment closed	4.00
4.	Difference per 100 pounds between the cost price and selling price	.63

Freights—

1.	Cost of freight on each of the 20 wethers, computed on the basis of weights	$0.43½
2.	Cost of freight on each of the 30 lambs pitted against the wethers, on the basis of weights	.23
3.	Cost of freight on a double-deck car from Culbertson, Montana, to St. Paul, 702 miles, with a cargo of 100 wethers and 187 lambs, including food	79.40

Weights—

		Lbs.
1.	Estimated average weight of each wether in Montana	106.
2.	Average weight of each wether when the experiment proper began, November 16th, 1896	116.8
3.	Average weight of each lamb pitted against the wethers on the same date	58.1
4.	Average weight of each wether at the close of the experiment, February 8th, 1897	140.3
5.	Average weight of each lamb on same date	77.1

Increase in Weight—

1.	Average increase in weight made by each wether during the experiment proper	23.4
2.	Average increase in weight of each lamb for the same period	19.0

	Lbs.
3. Average increase in weight per month made by each wether	8.4
4. Average increase in weight made by each lamb	6.8

Food Consumed—

1. Average amount of food consumed per day by each wether	4.02
2. Average amount of food consumed per day by each lamb	2.51

Cost of Increase—

1. Cost of making 100 pounds of increase with the wethers during the experiment proper	$4.92
2. Cost of making 100 pounds of increase with the lambs during the same period	3.97

Increase in Values—

1. Average value of each wether at the beginning of the experiment proper, November 16th, 1896.	3.87
2. Average value of each lamb at the same date	2.00
3. Average increase in value on each wether, shrunk weights not considered, during the experiment proper	1.74
4. Average increase in value on each lamb during the same period	1.76

Profits—

1. Average net profit on each wether during the experiment proper	.36
2. Average net profit on each lamb during the experiment proper	.85

CONCLUSIONS.

The following are the more important of the conclusions that may be drawn from the experiment:

1. That in this experiment the net profit in feeding one lamb for 84 days was 49 cents more than from feeding one wether for a similar period.

2. That this greater profit arose from the greater relative gains made by the lambs, and from the greater relative advance in the selling price as compared with the buying price.

3. That if as much profit is to be made from feeding wethers as from feeding lambs, it would seem to be necessary to buy them at a considerably less price per 100 pounds.

FATTENING RANGE WETHERS.

SECTION NO. 5.

THOMAS SHAW.

This experiment is virtually a repetition of the one conducted the previous winter in fattening range wethers, though in a somewhat modified form. The chief points of difference, however, relate to the duration of the experiment and the disposal of the wethers. In the experiment of 1896 and 1897, the feeding covered a period of 91 days, whereas in that of 1897-'98, it covered but 87 days. In the former the whole period of feeding was simultaneous with that of the feeding of the lambs pitted against them in the feeding contest. In the latter, although it commenced at the same date as the experiment with the lambs pitted against them, it only covered 87 days, whereas the feeding of the lambs covered 131½ days. And in the former the wethers and lambs were sold simultaneously, whereas in the latter the wethers were sold on January 28th, 1898, and the lambs were not sold until March 12th following.

Time Covered by the Experiment.—The preparatory experiment began November 2d, 1897, and covered 6 days. The experiment proper began November 8th and ended January 28th. The whole time of feeding therefore was 87 days. The wethers were then sold to Mr. F. W. Luley, of the Minnesota Transfer, and were disposed of in the Twin Cities. A number of them were served on the tables of the Commercial club of Minneapolis, and to the great satisfaction of the guests. The finish put upon the wethers, as shown later in Figures 205 and 206, was considered by the purchasers to be of the first order.

Objects Sought in the Experiment.—Chief among the objects sought in the experiment were the following: 1,

to determine the behavior of range wethers in a feeding contest with range lambs with reference, first, to relative increase in weight; second, to the cost of such increase and, third, to the consumption of food used in producing it; and 2, to determine the relative profit from feeding wethers and lambs respectively.

The Animals Used.—The wethers were bought by the Hon. W. M. Liggett, the director of the station, and the writer, from Wm. B. Shaw, Culbertson, Montana, in the autumn of 1897. Culbertson is on the line of the Great Northern railroad, and is 702 miles west from St. Paul. They formed part of a carload consisting of 25 wethers and 299 lambs that were purchased at the time. They reached the station Oct 20th, and were pastured on blue grass for 10 days. They were chosen on the ground of uniformity rather than on that of size. Some were yearlings and some were older. They were from Oxford Down sires and Merino grade dams of mixed breeding. On the whole they were better than the average range wether, but were somewhat more leggy than the average wether of the arable farm. They weighed 117 pounds each when they reached the farm, and when put under experiment, 10 days later, the weight was virtually the same.

Conditions Governing the Experiment.—Only 20 out of the 25 wethers purchased were fed, because of the want of room for a larger number. The other five were sold to the supply department of the School of Agriculture, and at a fair profit. They were fed in one division of the shed alongside that in which the lambs were kept which were pitted against them in the contest. They had access to a yard at will, save in stormy weather. The yard was on the north side of the shed. The wethers were weighed singly when put under experiment and every two weeks thereafter. Water and salt were also on hand all the time.

Food and Feeding.—The grain fed consisted of oilcake, wheat bran, corn and oats, fed in the proportions of 1, 2, 3

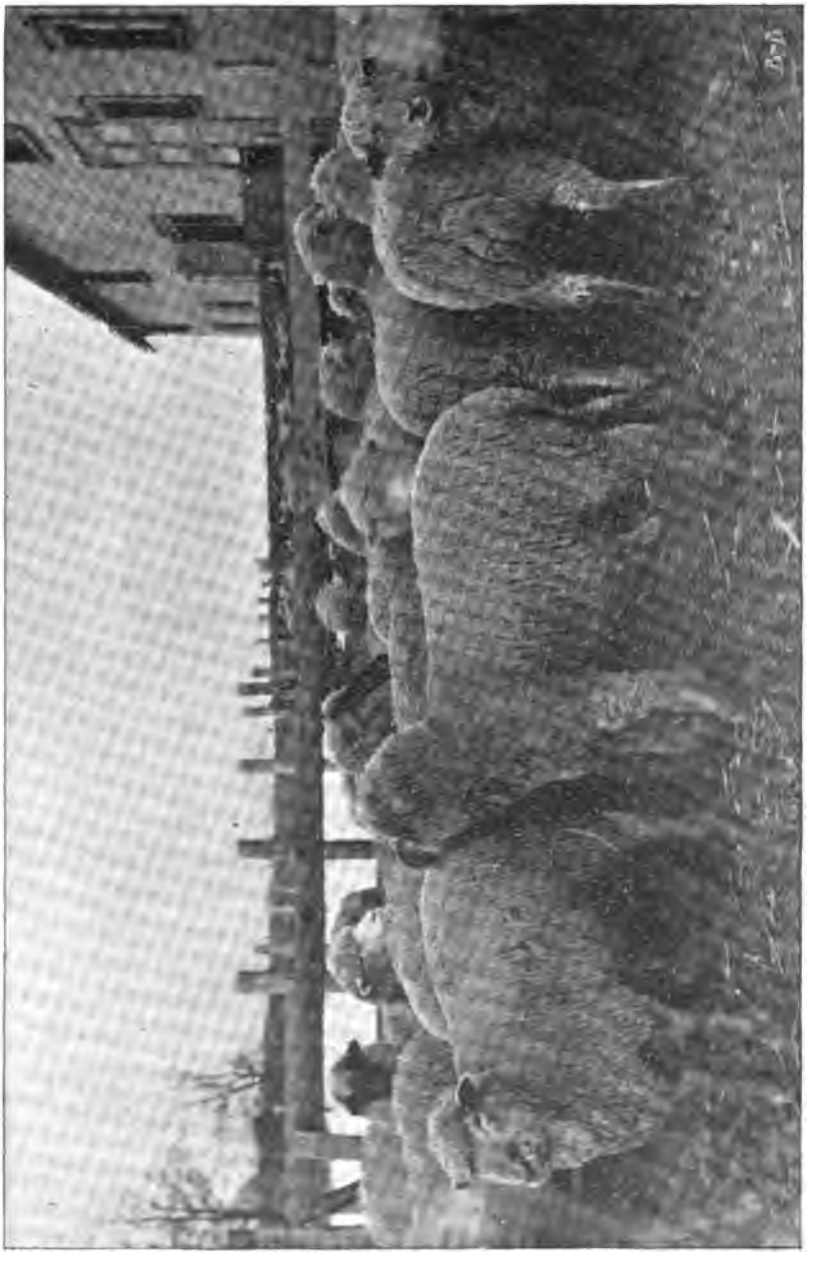


Fig. 204.—The Wethers when Finished.

and 4 parts, by weight, respectively. The hay fed consisted of clover and timothy, the former predominating. They were also fed sorghum ensilage after December 28th. The corn and barley were fed whole and the hay was given uncut. They were given of each kind of food what they would eat up clean and no more. All the food fed was given in two feeds per day, save the ensilage, which was fed but once. The food ration was the same in kind as that given to the lambs pitted against them in the feeding contest, and the general treatment was the same. These lambs are described as lot 1, in Bulletin No. 57, section 3. In the said bulletin all the requisite particulars are given relating to the feeding of the lambs.

Estimated Value of the Food.—The food was charged at the average market values in the state when delivered at the place of sale. These values were fixed as follows:

Oilcake, per ton	$22.00
Wheat bran, per ton	7.50
Corn, per bushel of 56 pounds	.22
Barley, per bushel of 48 pounds	.20
Oats, per bushel of 32 pounds	.17
Hay, per ton	4.00
Sorghum ensilage, per ton	1.20

Food Consumed.—Table CII. gives the aggregate amounts of the various food factors consumed during the experiment proper, the average amounts of the same, and the average amount consumed by one animal per day.

TABLE CII.—Food Consumed.

	Aggregates of Food Consumed.	Averages of Food Consumed.	Average Consumption per Animal per day.
	Lbs.	Lbs.	Lbs.
Grain	4,816	142.3	2.78
Hay	2,925	146.2	1.68
Ensilage	505	25.2	.81
Totals	8,276	413.7	5.27

The total consumption of food per day by the wethers was 5.27 pounds as against 2.85 pounds consumed by the lambs fed on a similar ration during 91 days of practically simultaneous feeding. In proportion to the live weight, the consumption of food by the wethers was a little less. The average weight of the wethers when put under experiment was, as stated, 117 pounds, while that of the lambs was 60.8 pounds. On the other hand, the relative gains made by the lambs in proportion to the food fed was much greater, as will be shown below.

Value of Food Consumed.—The cost of the various items of food fed was as follows:

Oilcake	$5.35	
Wheat bran	3.63	
Corn	5.71	
Oats	10.30	
Total cost of grain		$24.99
Hay		6.58
Ensilage		.30
Total		$31.87

The cost therefore of food per head for one wether for 87 days was $1.59, while for one lamb, similarly fed for 91 days, it was but $1.04. It is also worthy of note that the 1,938 pounds of oats fed cost nearly twice as much as the 1,453 pounds of corn, hence the great importance of noting carefully the relative cost of foods when making up a food ration.

Weights of the Wethers.—The following is a synopsis of the weights and gains made by the wethers during the experiment proper:

	Lbs.
Aggregate weights on November 2d, 1897, when the experiment began	2,341
Aggregate weights on January 28th, 1898, when it closed	3,000
Aggregate gains in 87 days	659
Average weight when the experiment began	117
Average weight when the experiment closed	150
Average increase in weight	33
Average increase in weight per month of 30 days	11.4

These were excellent gains, but it should be noted that the period of feeding was a short one. The gains made by the lambs during practically the same period were 10.2 pounds per month.

The wethers were sold on a shrink of 4 per cent, which amounted to 6 pounds per animal. This reduced the aggregate weight from 3,000 pounds to 2,880 pounds, and the average weight from 150 pounds to 144 pounds.

Financial Statement.—The wethers were sold for 4½ cents per pound live weight. The account therefore stands as below:

Received for 20 wethers when delivered on January 28th, at the Minnesota Transfer	$129.60
Total cost of the same	120.83
Total net profit	$8.77
Average net profit per head	.44

The outlay was made up of the following items: Cost in Montana, 2,341 pounds at $3.33 per hundred, $77.96; Pasture for 10 days, $1.00; Freight, $10.00; Food for 87 days, $31.87. The profit on the 20 wethers for the 87 days feeding without shrink was 71 cents per animal, while the profit from feeding one lamb for 91 days on the same basis was $1.91. This great difference arose, as in the experiment of the previous year, first, from the less consumption of food by the lambs in proportion to the gain, and second, from the greater advance in the value of the lambs.

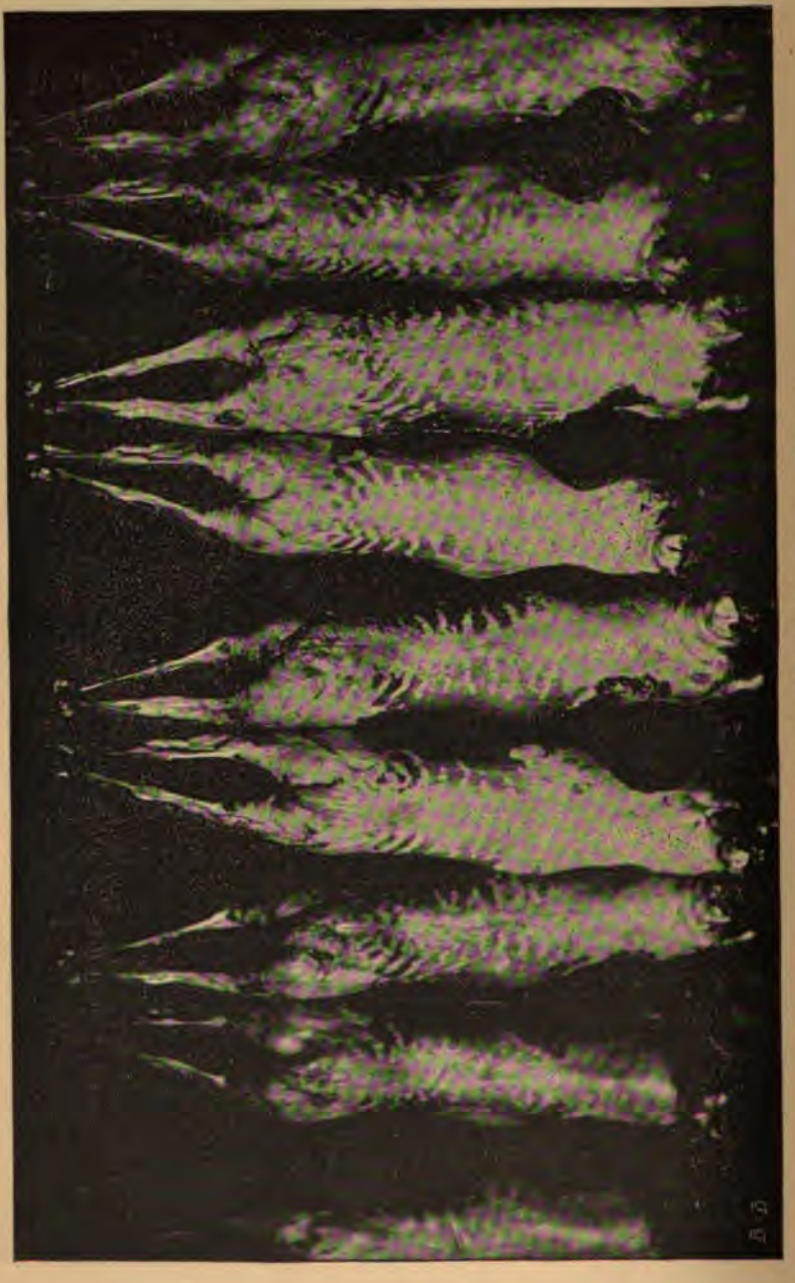


Fig. 205.—Rear View of Wethers, when Dressed.

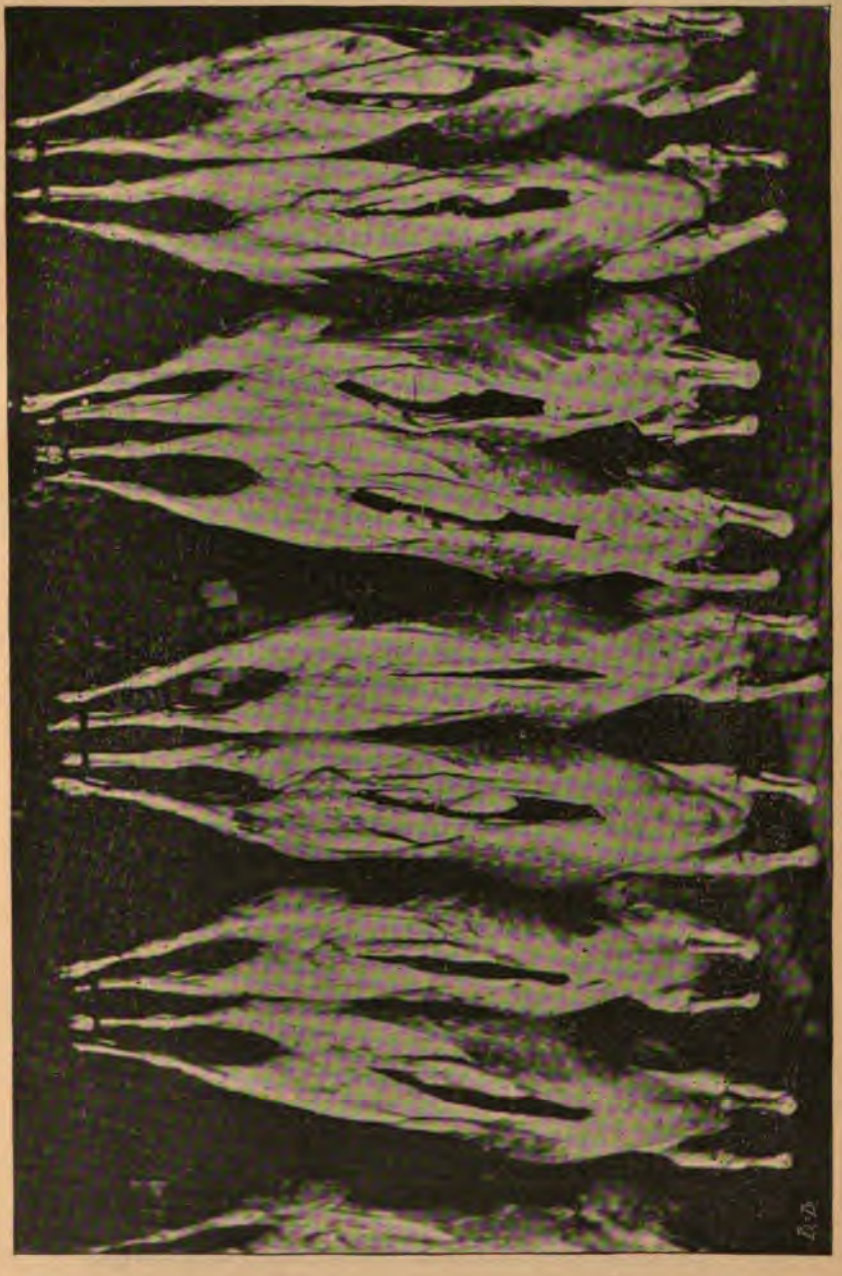


Fig. 206.—Front View of Wethers when Dressed.

While the lambs consumed but 2.85 pounds of food per head per day, as stated, and made a monthly gain of 10.2 pounds, the wethers consumed 5.27 pounds of food per head per day and made a monthly gain of 11.4 pounds. And while the lambs advanced in value from $3.45 per 100 pounds to $5.50, the wethers advanced from $3.80 per 100 pounds to $4.50, that is to say, while the lambs advanced $2.05 per 100 pounds, the wethers only advanced 70 cents per 100 pounds.

In feeding lambs as against wethers, therefore, when bought at the same price per 100 pounds, under normal conditions, the lambs may always be expected to make a greater gain from the food fed, and to make more of an advance on the selling price as compared with the cost price. These two facts should never be lost sight of when deciding whether lambs or wethers shall be fed. This advantage in favor of the lambs is partially offset by the greater weight of the wethers at the time of purchase, so that there is a greater relative profit on the weight at the time of purchase, in proportion to the advance in price that is made when the animals are sold.

The contrast may be shown in another way. The cost of making 100 pounds of increase with the wethers in this experiment was $4.83, and the selling price was $4.50 per hundred. Each 100 pounds of increase, therefore, made while feeding the wethers, cost 33 cents more than it was worth. The cost of making 100 pounds of gain with the lambs during practically the same period and on similar foods was $3.83, and the selling price was $5.50. Each 100 pounds of increase, therefore, made by the lambs was worth $1.67 more than it cost to make it.

It should be mentinoed also that the wethers cost more when bought. But the difference was only 8⅓ cents per 100 pounds more for the wethers than for the lambs. The latter were valued at 3.25 per hundred when bought, although the whole lot of lambs cost but $3.00 per hundred. Had the

wethers been purchased at the same price as the value put upon the lambs, the final outcome would be more favorable to the wethers to the extent of only 10 cents per head.

IMPORTANT FACTS SUMMARIZED.

Values—

1. Price paid per hundred for the wethers in Montana $3.33
2. Value per hundred on the basis of cost when the experiment began 3.80
3. Value per hundred, shrunk weight, when delivered at the Minnesota Transfer, January 28th, 1898 ..... 4.50
4. Difference per hundred between cost price and selling price ..... .70

Freights—

1. Cost of freight on each of the 20 wethers computed on the basis of weights 50
2. Cost of freight on each of the 30 lambs pitted against the wethers in the experiment on the basis of weights ..... .25½
3. Cost of freight on a double-deck car from Culbertson, Montana, to St. Paul, 702 miles, with a cargo of 25 wethers and 299 lambs, including food 82.10

Weights—

	Lbs.
1. Average weight of each wether in the experiment in Montana, and also when the experiment began	117
2. Average weight of each lamb pitted against the wethers when the experiment began	60.8
3. Average weight of each wether at the close of the experiment on feed 87 days	150
4. Average weight of each lamb when on feed 91 days	92

Increase in Weight—

	Lbs.
1. Average increase in weight made by each wether during 87 days of feeding	33
2. Average increase in weight made by each lamb during 91 days of feeding	31
3. Average increase in weight per month made by each wether	11.4
4. Average increase in weight per month made by each lamb	10.2

Food Consumed—

	Lbs.
Average amount of food consumed per day by each wether	5.27
Average amount of food consumed per day by each lamb	2.85

Cost of Increase.—

1. Cost of making 100 pounds of increase in weight with the wethers during the experiment proper...	$4.83
2. Cost of making 100 pounds of increase with the lambs	3.83

Profits.—

1. Average value of each wether at the beginning of the experiment, November 2d, 1897	4.45
2. Average value of each lamb at the beginning of the experiment, November 1st	2.10
3. Average value of each wether at the close of the the experiment, January 28th, 1898	6.75
4. Average value of each lamb on January 31st, '98	5.05
5. Average increase in value on each wether	2.30
6. Average increase in value on each lamb	2.95
7. Average profit on each wether, shrunk weights not considered	.71
8. Average profit on each lamb on a similar basis...	1.91

CONCLUSIONS.

The following are among the more important of the conclusions based upon the experiment:

1. That when wethers and lambs are bought at the same price per pound and are fattened under similar conditions, the lambs are likely to bring considerably more profit.

2. This increased profit is likely to arise first, from the greater relative advance at which the lambs will probably be sold, and second, from the greater relative gains which the lambs are likely to make on a given amount of food.

3. And this profit may be expected to increase with the decrease in the difference between the weight of the wethers and lambs respectively at the time of purchase, because of the influence which weight at the beginning of an experiment exercises upon any advance made in mutton values.

AVERAGES FROM TWO EXPERIMENTS.

Certain averages are now submitted gleaned from the two experiments in feeding wethers.

Period of Feeding—	Days
1. Average time covered by the experiment proper....	82½
2. Average time covered by the whole period of feeding	89
Values—	
1. Average value of the wethers per 100 pounds on the basis of cost when the feeding began.....	$3.58½
2. Average value per 100 pounds, shrunk weight, when the lambs were sold.....	4.25
3. Difference per 100 pounds between the cost price and the selling price.....	.66½
Increase in Value—	
1. Average value of each wether when the feeding period began.....	4.16
2. Average value of each wether, without shrink, when the feeding period closed.....	6.18

3. Average value of each wether, with shrink, when the feeding period closed	$5.93½
4. Average increase in value of each wether during the feeding period	2.02

Weights—

	Lbs.
1. Average weight of one wether when the period of feeding began	115
2. Average weight of each wether when the period of feeding closed, that is to say when 89 days on food	145

Increase in Weight.—

1. Average increase in weight of each wether from feeding for 89 days	30.1
2. Average increase in weight of each wether per month of 30 days	10.2

Food Consumed.—

1. Average of grain consumed per day by each wether	2.89
2. Average of food consumed per day by each wether	4.65

Cost of Increase.—

1. Average cost of making 100 pounds of increase in weight during the experiment proper	$4.87½
2. Average cost of making 100 pounds of increase in excess of the price obtained for it	.62½

Profit.—

1. Average profit on each wether during the period of feeding, shrunk weight not included	.65
2. Average net profit on each wether	.40

TABLE CIII.—Normal Temperature, Monthly and Annual, 1897.
Obtained from Stations in Minnesota Having a Record of Five or More Years.

STATIONS.	Length of Record in Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Northern Section														
Ada	5	3.2	8.6	20.9	45.5	57.9	64.8	69.0	65.6	58.4	42.9	22.0	10.5	38.5
Crookston	9	−0.8	6.1	19 2	42.9	53.5	65.5	71.3	65.5	57.3	43.0	22.5	12.6	38.3
Duluth	27	8.7	12.9	23.9	37.7	48.8	57.8	65.9	64.7	56.2	44.9	29.4	17.8	38.2
Lake Winnibigoshish	10	4.6	7.6	20.2	40.1	50.9	63.3	69.3	63.5	56.0	41.6	23.3	14.0	37.6
Leech Lake Dam	10	3.9	7.8	19.4	40.4	50.2	63.6	66.5	62.8	55.4	41.5	22.7	14.8	37.4
Moorhead	17	−1.6	4.6	19 9	38.3	52.8	65.7	67.2	64.4	53.0	40.5	22.4	10.6	36.5
Park Rapids	8	−1.7	5.6	19.6	40.8	53.1	63.3	68.1	63.0	56.3	40.8	21.9	12.0	36.9
Pine R. Dam	11	3.3	7.3	20.0	40.6	52.4	65.3	69.7	65.5	57.5	42.5	23.9	14.5	38.5
Pokegama	11	2.2	6.4	19.4	38.2	49.6	62.5	66.1	62.6	53.2	39.3	21.6	13.2	36.0
Sandy L. Dam	5	4.4	9.8	21.1	39.9	52.0	64.1	67.6	64.1	56.6	42.5	22.1	12.8	38.2
Middle Section														
Bonniwells	5	6.6	15.6	24.8	47.6	59.1	68.9	72.8	69.0	62.6	47.3	27.0	17.4	43.3
Collegeville	5	9.8	15.6	27.3	46.0	58.2	68.4	72.6	69.1	62.5	47.6	27.5	19.1	43.6
Fergus Falls	6	3.9	11.1	22.5	43.0	55.3	66.8	70.3	66.7	60.0	45.2	23.7	13.5	40.1
Long Prairie	6	3.3	9.4	21.5	41.9	55.5	65.0	68.9	64.8	58.6	43.2	22.8	15.5	39.7
Maple Plain	6	7.4	15.1	26.4	45.1	56.4	67.7	72.1	68.8	61.7	46.9	26.7	17.8	42.6
Morris	13	3.7	9.3	22.8	44.4	55.2	66.4	72.1	67.0	59.5	44.7	26.3	14.3	40.7
St. Cloud	22	9.0	12.7	25.7	43.2	56.1	66.8	71.1	69.5	58.5	44.8	26.5	18.2	41.6
St. Olaf	5	3.6	11.5	22.1	43.3	55.2	66.7	69.8	66.6	59.5	44.6	23.4	13.8	40.0
Willmar	5	6.6	12.8	23.4	44.3	56.4	66.7	70.5	66.9	60.1	44.6	24.4	16.5	41.1
Southern Section														
Albert Lea	8	7.7	16.1	27.1	45.5	58.3	67.0	72.2	67.7	60.6	46.3	28.2	17.1	42.3
Bird Island	8	5.2	11.6	25.5	45.0	56.8	66.7	71.5	67.6	60.8	47.1	26.8	16.6	40.2
Blooming Prairie	5	9.0	14.4	26.8	46.1	57.4	68.0	71.5	68.5	61.8	47.4	26.5	18.1	43.0
Caledonia	6	13.6	17.1	28.5	46.4	57.0	67.9	71.6	62.4	62.3	47.9	30.0	20.0	44.4
Camden	6	9.1	14.4	25.9	45.1	56.9	66.8	71.0	67.6	61.3	48.6	26.2	20.0	42.7
Farmington	10	11.0	14.1	26.3	45.3	55.6	67.0	70.9	68.2	60.6	46.4	28.1	21.1	42,9
Grand Meadow	10	10.5	13.8	24.8	44.2	53.9	67.3	72.0	66.8	59.3	44.6	27.4	20.2	42.0
Minneapolis	38	8.8	14.4	25.1	44.2	57.5	67.2	71.6	68.3	59.8	45.9	28.9	16.2	42.3
Minnesota City	5	13.2	18.1	30.1	48.5	59.1	68.5	71.3	68.3	62.0	48.4	30.2	22.6	45.0
Montevideo	8	7.4	13.0	24.2	46.0	56.3	66.7	70.6	68.2	62.4	48.1	27.5	20.5	42.6
New Ulm	18	10.9	16.1	25.2	45.6	60.7	69.3	72.1	71.6	62.2	45.2	30.7	17.9	44.0
Rolling Green	11	8.9	13.7	25.8	45.1	56.0	66.8	71.3	68.3	62.5	46.2	28.4	21.0	42.8
St. Charles	8	12.0	16.6	26.2	44.8	56.3	67.1	69.8	66.8	60.7	46.1	28.5	22.2	43.1
St. Paul	26	9.9	15.5	28.5	45.8	57.2	67.2	71.5	69.1	59.7	46.9	29.8	18.8	43.4
Wabasha	6	11.6	16.9	28.6	48.1	59 4	68.8	72.7	69.2	62.9	47.1	29.3	21.0	44.8

TABLE CIV.—Normal Precipitation, Monthly and Annual, 1897.
Obtained from Stations in Minnesota Having a Record of Five or More Years.

STATIONS.	Length of Record in Years.	January.	February	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
NorthernSecti'n														
Ada	5	0.53	0.55	0.72	2.42	2.42	3.90	3.53	1.15	1.28	0.91	0.76	0.28	18.43
Crookston	8	0.68	0.99	1.05	2.01	2.85	3.93	3.50	2.69	1.71	1.55	0.80	0.21	22.00
Duluth	27	1.07	1.11	1.66	2.42	3.68	4.59	3.72	2.34	3.86	2.59	1.61	1.36	31.01
Lake Winnibigoshish	10	0.90	0.80	1.36	2.20	3.03	3.84	3.84	2.94	2.65	1.51	0.98	0.67	24.72
Leech L'ke Dam	10	0.88	0.88	1.38	2.39	3.25	3.30	4.13	2.61	2.30	1.58	0.99	0.75	25.64
Moorhead	17	0.73	0.83	0.87	2.23	2.50	4.36	3.91	2.68	2.09	1.92	0.92	0.73	25.68
Park Rapids	8	1.01	0.70	0.92	3.01	2.75	5.36	4.02	2.05	1.50	1.65	0.99	0.64	24.60
Pine R. Dam	11	1.08	0.84	1.31	2.78	3.15	4.16	3.31	2.02	2.00	1.71	1.08	0.70	25.14
Pokegama	11	1.09	0.91	1.58	2.65	3.24	4.87	4.10	3.04	2.27	1.84	1.14	0.93	27.66
Sandy L. Dam	5	1.46	0.95	1.75	3.51	3.46	2.35	4.31	2.53	1.99	2.04	1.03	0.94	26.25
Middle Section.														
Alexandria	10	0.81	0.74	1.28	2.98	2.86	3.80	3.59	1.48	2.20	1.23	0.39	0.54	23.48
Beardsley	5	1.28	0.70	1.28	3.58	.....	3.80	2.79	1.97	1.58	1.91	1.10	0.38	.....
Bonniwell	5	0.61	0.39	1.83	3 04	2.46	2.58	2.22	2.19	3.59	2.03	0.87	0.53	22.34
Collegeville	5	0.63	0.28	1.10	3.71	2.78	3.49	3 20	1.78	2.26	1.15	0.81	0.26	21.45
Fergus Falls	10	0.74	0.56	1.03	2.60	3.18	3.58	3.77	2.27	1.85	1.37	0.67	0.68	22.30
Long Prairie	5	0.94	0.28	1.29	4.50	2.22	3.74	3.20	2.24	2.20	1.53	1.00	0.37	24.51
Maple Plain	6	1.51	1.02	2.59	3.39	3.14	3.83	3 40	3.17	2.67	1.90	1.46	1.06	29.24
St. Cloud	5	1.20	0.66	1.86	4.37	3.94	4.51	3 81	1.88	3.14	2.13	1.27	0.47	29.24
St. Olaf	5	1.14	0.73	1.32	3.47	3.45	4.59	3.77	2.12	1.66	1.25	0.97	0.36	25.47
Willmar	5	0.88	0.45	1.38	4.07	2.96	5.33	2.68	3.56	2 03	1.04	1.04	0.44	25.96
SouthernSecti'n														
Albert Lea	8	1.29	0.61	1.46	2.89	2.80	3.40	3.50	2.81	3.20	1.36	1.49	0.96	25.86
Bird Island	8	0.72	0.72	0.98	3.34	3.15	3.25	2.25	2.68	2.59	1.19	0.90	0.44	23.21
Blooming P	6	0.62	0.76	1.34	3.15	3.65	4.44	3.16	2.13	2.21	1.79	1.06	1.24	24.81
Caledonia	6	1.38	0.91	1.78	4.14	3.88	4.45	2.13	2.18	3.37	1.79	1.73	1.22	28.95
Camden	6	0.78	0.31	1.69	5.38	3.58	3.40	2.65	2.42	2.42	1.52	0.93	0.57	25.66
Farmington	10	1.01	1.26	2.27	2.96	3.11	4.19	3.12	2.89	2.46	1.75	1.28	1.69	27.99
G'd Meadow	10	0.89	0.91	1.11	2.59	3.87	6.12	3.32	2.43	2.13	1.90	0.88	1.14	27.29
Minneapolis	32	1.23	1.11	1.61	2.52	3.44	4.29	3.42	3.58	3.31	1.94	1.35	1.17	25.80
Minnesota City	5	1.13	0.51	1.13	3.85	3.35	3.98	2.41	2.15	2.13	1.90	1.36	1.02	24.92
Montevideo	8	0.76	0.75	1.70	3.57	2.84	3.78	2.26	1.78	1.49	1.31	0.64	0.73	21.51
New Ulm	18	0.95	0.96	1.47	1.96	3.14	3.70	3.52	3.03	2.63	1.85	1.17	0.64	25.02
Rolling Green	11	1.13	0.92	1.52	3.89	3.85	3.65	2.16	2.19	2.26	1.20	1.00	1.30	25.07
St. Charles	8	1.31	1.14	1.34	3.87	3.78	4.35	2.56	3.75	2.58	2.67	1.27	1.55	30.12
St. Paul	27	0.97	0.92	1.43	2.47	3.40	4.35	3.34	3.30	3.00	1.89	1.02	1.28	27.47
Wabasha	5	1.46	1.08	1.66	3.80	3.20	2.88	3.67	1.97	3.12	2.07	1.14	0.39	26.44

TABLE CV.—Monthly and Annual Mean Temperature for the Year 1897.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Northern Section.													
Ada	.....	6.0	13.7	44.6	56.2	61.6	70.2	64.6	65.2	47.4	21.2	7.4	.....
Bemidji	–1.2	7.1	14.6	45.7	55.9	65.1	.....	68.6	.....	.....	.....	.....	.....
Crookston	–0.6	7.0	13.6	45.6	55.0	61.4	70.0	68.6	63.6	47.6	20.8	9.6	38.2
Detroit City	1.9	11.4	17.1	42.3	58.2	58.6	71.0	63.2	69.0	.....	21.5	5.6	.....
Duluth	9.4	18.6	21.8	40.0	48.4	54.2	66.4	63.8	62.6	48.6	26.2	14.2	39.5
Koochiching	.....	7.3	14.4	38.8	.....	.....	68.2	60.3	60.6	45.0	18.8	6.4	.....
*Lake Winnebigoshish	1.2	10.1	17.9	38.5	51.6	57.9	68.0	62.3	62.1	45.0	20.7	6.6	36.8
Lambert	0.8	8.6	14.2	40.2	53.6	59.2	71.3	61.8	60.8	45.8	20.0	6.0	36.9
*Leech Lake Dam	–0.9	9.1	17.8	41.0	51.4	58.5	69.2	62.1	63.0	47.2	22.4	6.6	37.3
Lutsen	10.2	17.4	20.4	35.8	44.7	52.4	61.0	60.5	57.1	45.8	25.8	15.2	37.2
Moorhead	1.7	7.6	14.5	42.6	56.1	62.8	70.3	63.9	62.1	45.7	21.4	9.2	38.2
Mountain Iron	2.7	12.0	19.8	39.2	49.4	56.8	67.4	58.6	59.6	42.8	17.6	3.2	35.8
Park Rapids	1.5	10.6	17.4	41.0	51.6	57.4	69.2	61.1	61.8	46.7	22.0	6.5	37.2
*Pine River Dam	3.5	13.7	20.3	42.2	53.8	59.6	70.2	64.3	62.0	47.3	24.0	8.4	39.1
*Pokegama	1.3	9.1	17.8	42.3	50.8	57.3	68.3	60.3	61.6	45.7	18.5	5.5	36.5
Roseau	–0.5	4.8	11.4	39.4	.....	.....	67.2	.....	.....	43.9	17.0	4.0	.....
*Sandy Lake Dam	3.7	12.9	20.2	41.1	51.4	58.2	69.6	61.5	62.4	46.8	22.2	8.5	38.2
Tower	2.9	9.6	14.6	35.5	50.0	54.7	67.5	58.5	57.2	40.1	18.4	3.8	34.4
Two Harbors	11.3	19.3	24.3	40.0	47.0	54.0	64.0	62.5	60.7	48.1	27.5	15.4	39.5
Middle Section,													
Alexandria	4.1	13.8	15.4	42.4	54.6	60.5	71.1	64 1	65.3	49.6	26.6	10.7	39.8
Beardsley	4.6	11.5	15.9	45.2	.....	62.1	70.6	63.6	67.6	49.2	26.0	13.3	.....
Bonniwell	8.6	17.6	21.4	45.8	56.1	62.9	73.0	65.4	65.1	52.1	29.4	13.8	42.6
Collegeville	8.4	18.0	22.6	44.9	56.6	62.7	72.8	65.5	66.4	51.4	29.2	15.0	42.8
Fergus Falls	7.0	12.3	18.2	43.5	55.5	62.4	71.6	64.2	65.6	49.4	25.0	.....	.....
Glenwood	3.6	13.8	19.1	42.6	55.4	62.4	72.2	64.2	65.6	.....	25.1	11.6	.....
Lawrence	8.2	.....	.....	43.7	.....	64.4	70.8	64.8	.....	52.0	.....	.....	.....
Long Prairie	4.6	14.6	19.7	43.0	54.0	60.9	72.1	63.9	64.4	48.1	25.0	.....	.....
Maple Plain	6.8	18.2	22.0	45.2	56.2	65.2	74.3	67.1	67.3	52.5	28.0	13.8	43.0
Milaca	.....	17.0	25.3	44.4	.....	51.0	73.8	67.8	.....	.....	.....	13.0	.....
Milan	4.9	12.0	17.0	45.2	57.3	63.6	72.0	64.5	68.9	50.4	24.1	12.6	41.0
Morris	5.0	13.2	17.4	44.0	57.0	63.6	72.7	65.8	66.0	50.3	26.4	12.6	41.2
New London	2.6	14.2	16.4	40.4	53.8	57.2	71.4	66.0	65.4	48.6	25.5	11.8	39.4
St. Cloud	5.7	16.0	19.4	41.4	53.8	61.2	71.7	64.8	64.3	49.6	24.6	9.0	40.1
St. Olaf	4.4	12.8	18.4	43.2	55.6	61.5	71.0	63.8	64.6	48.4	25.0	10.2	39.1
Willmar	6.2	13.6	19.3	44.1	55.0	62.8	72.0	64.4	65.2	49.8	26.4	12.3	40.9

TABLE CV.—Continued.
Monthly and Annual Mean Temperature for the Year 1897.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Southern Section.													
Albert Lea	11.4	20.2	24.6	.....	.....	65.2	.....	.....	67.2	53.2	30.2	13.2	.....
Bingham Lake	10.8	18.6	22.0	45.7	62.8	65.0	74.6	75.6	77.4	.....	32.4	16.0	.....
Bird Island	8.5	16.0	20.2	44.9	56.0	63.0	71.4	64.4	66.4	50.6	27.7	14.3	42.0
Blooming Prairie	9.8	18.9	24.6	44.0	55.0	65.0	72.1	64.9	66.8	51.8	27.8	13.0	42.8
Caledonia	13.6	21.8	26.6	46.2	56.6	65.2	73.2	65.8	67.1	54.6	30.5	15.4	44.7
Camden	9.0	16.6	21.2	45.2	57.0	64.0	72.1	64.0	68.2	49.5	28.1	16.1	42.6
Faribault	6.6	18.3	24.2	44.4	55.3	63.6	74.2	66.6	68.2	52.8	29.3	14.4	43.1
Farmington	7.0	16.5	20.9	42.8	53.8	61.6	70.6	63.6	64.4	49.4	24.8	11.6	40.6
Glencoe	8.2	13.2	17.4	42.7	.....	.....	71.6	64.8	67 0	51.8	28.8	13.2	.....
Grand Meadow	10.4	18.3	23.6	44.3	54.5	64.6	73.0	65.0	67 0	51.4	26.8	10.0	42.4
La Crosse, Wis	14.0	22.0	27.2	46.4	57.4	66.7	74.6	66.6	68.0	55.2	32.7	16.8	45.6
Lake City	12.5	20.6	25.2	45.9	57.1	65.6	73.3	66.0	68.0	53.3	30.0	14.8	44.4
Lakeside	6.4	14.6	20.0	45.0	55.1	64.0	72.2	64.8	65.8	50.0	26.8	13.2	41.5
*Le Sueur	8.9	19.0	24.5	48.4	55.7	65.9	73.7	65.9	64.6	52.3	28.9	17.2	43.8
Lu Verne	10.4	17.6	23.8	45.6	55.0	65.1	72.6	64.3	67.8	51.5	29.8	16.6	43.3
Lynd	.....	.....	.....	.....	.....	.....	72.5	64.8	67.6	49.8	27.4	14.4	.....
*Maplewood	.....	.....	.....	45.1	57.8	64.4	73.5	65 9	66.7	51.7	29.8	16.4	.....
*Mazeppa	13.2	16.3	25.8	42.2	55.4	64.7	75.6	65.8	68.2	.....	.....	.....	.....
Minneapolis—W. B.	10.6	20.0	24.7	46.4	56.8	64.4	73.9	66.4	67.9	53 4	29.5	15.2	44.1
" —Vol. 1	8.6	19.2	23.5	45.2	56.6	64.7	73.8	66.8	66.3	51.8	28.5	15.2	43.4
" —Vol. 2	8.2	18.6	23.4	44.0	54.9	63.4	72.5	63.6	64.5	50.3	26.7	13.2	41.9
*Minnesota City	15.7	23.1	28.9	47.4	57.4	66.8	73.1	66.5	66.6	54.7	31.1	16.3	45.6
Montevideo	5.4	14.2	17.8	44.4	57.3	62.8	71.9	65.3	67.8	51.5	27.8	15.0	41.8
*New Richland	9.6	18.7	24.9	46.0	56.4	66.3	73.6	65.6	66.6	52.2	29.9	13.2	43.6
New Ulm	9.0	18.3	23.1	45.8	57.0	65.5	73.5	65.4	68.0	51.6	28.6	16.3	43.5
Pleasant Mounds	9.6	17.9	23.6	46.0	56.0	64.3	71.7	.....	.....	53.6	31.0	16.0	.....
Rolling Green	9.3	18.0	22.6	44.1	55.3	64.0	72.2	65.8	68.2	53.2	29.0	15.4	43.1
*Shakopee	9.2	21.4	22.4	47.5	56.1	64.2	74.8	67.1	67.8	52.5	29.6	16.1	44.1
St. Charles	12.6	20.0	24.6	44.9	56.4	65.0	72.2	64.6	66.7	53.3	30.5	13.6	43.7
St. Paul	9.4	18.6	24.2	45.8	56.8	64.2	73.8	66.3	67.6	53.0	29.3	15.4	43 7
St. Peter	.....	23.8	.....	.....	.....	.....	72.9	65.8	67.6	55.2	33.2	17.8	.....
*Wabasha	12.7	20.7	26.4	47.9	56.8	65.0	73.2	65.1	65.7	53.3	30.2	15.2	44.4
Worthington	9 0	16.2	21.8	42.3	55.6	64.0	71.9	64.0	68.4	52.0	29.2	15.2	42.5
*Zumbrota	10.5	20.7	25.6	44.7	56.4	64.9	73.8	.....	.....	52.5	28.8	14.7	.....

TABLE CVI.—Monthly and Annual Precipitation for the Year 1897.

STATIONS.	January.	February	March	April	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Northern Section.													
Ada	0.44	0.74	0.33	0.70	0.48	5.96	7.83	1.53	1.10	1.09	0.04	0.22	20.46
Bemidji	.....	2.10	1.40	0.90	0.03	8.70	8.60	1.40	0.70	.....	.....	.....	.....
Crookston	0.37	2.30	0.94	0.39	1.21	3.93	8.45	1.15	1.02	1.33	0.20	0.25	21.54
Detroit City	1.72	1.07	1.44	1.75	1.34	6.61	7.93	0.95	1.00	2.05	0.20	†	26.06
Duluth	1.48	2.21	1.34	0.72	1.63	3.48	9.29	3.91	3.14	2.11	0.78	0.85	30.94
Koochiching	.....	2.35	2.55	0.28	.....	.....	6.18	2.41	0.20	2.12	0.73	0.71	.....
Lake Winnibigoshish	2.30	1.62	1.58	1.03	1.13	4.82	9.87	2 32	0.61	1.27	0.40	0.60	27.55
Lambert	0.85	1.40	1.01	†	0.67	3.85	9.80	1.18	0.79	0.55	0.10	0.55	20.75
Leech Lake Dam	1.83	1.97	1.00	1.46	0.98	5.98	6.00	2.18	1.12	1.49	0.24	0.59	25.44
Lutsen	2.41	1.82	1.81	1.18	2.47	2.51	9.99	2.86	2.58	2.39	0.87	0.48	31.37
Moorhead	1.56	1.52	1.34	0.92	0.80	7.42	8.02	0.88	0.94	1.84	0.28	0.28	25.80
Mountain Iron	3.30	3.00	0.70	0.20	1.88	3.27	8.75	4.38	2.12	2.24	0.25	.....	.....
Park Rapids	2.25	1.56	1.10	2.00	1.05	7.49	10.16	1.12	0.43	1.27	0.38	0.62	29.43
Pine River Dam	2.79	2.57	2.17	1.39	1.33	5.88	8.02	1.20	1.71	1 44	0.53	0.40	29.43
Pokegama	1.74	1.73	2.15	1.63	1.50	5.01	7.53	3.37	1.29	1.27	0.35	0.67	28.24
Roseau	1.51	1.14	.....	0.24	.....	2.04	6.58	.....	.....	1.57	0.77	0.57	.....
Sandy Lake Dam	2.18	2.45	2.18	0.53	1.89	5.43	13.41	1.65	2.04	1.33	0.32	0.60	34.01
Tower	1.92	1.90	1.50	0.70	1 60	3.00	9.50	4.65	1.60	2.05	1.30	1.00	30.72
Two Harbors	1.94	2.58	2.32	1.18	2.55	4.07	9.99	4.11	3.72	2.86	0.52	0.52	36.36
Middle Section.													
Alexandria	2.15	1.39	1.51	1.57	0.59	5.50	8.19	2.12	3.73	1.36	0.43	0.13	28.97
Beardsley	1.83	0.82	1.13	1.76	.....	6.54	5.35	2.01	1.93	2.50	0.71	0.39	.....
Bonniwell	1.12	0.74	2.52	1.30	0.65	.....	5.62	1.68	6.50	2.00	0.88	0.13	.....
Collegeville	1.22	0.64	2.50	1.25	1.48	4.88	6.84	2.71	3.45	1.12	0.35	0.04	26.18
Fergus Falls	1.64	0.91	1.46	1.33	1.52	4.86	3.00	1.97	0.58	1.85	0.28	0.61	20.01
Glenwood	1.50	0.94	1.51	2.49	1.22	5.94	8.37	5.55	4.00	.....	1.03	0.45	.....
Lawrence	2.75	1.45	.....	0.10	.....	2.84	5.35	0.90	0.29	.....	.....	.....	.....
Long Prairie	1.52	0.73	1.61	1.57	1.56	5.75	5.09	1.21	0.28	1.04	0.52	0.10	20.98
Maple Plain	2.26	1.34	4.22	1.38	1.45	6.26	4.91	2.48	2.69	1.66	1.01	0.24	29.90
Milaca	.....	2.70	1.36	.....	3.50	.....	12.81	1.37	3.51	.....	.....	0.29	.....
Milan	4.80	1.32	1.79	2.29	0.86	5.74	3.48	0.30	0.85	1.12	0.53	0.42	23.50
Morris	1.42	1.25	2.50	2.53	0.90	5.12	9.30	1.11	3.60	1.47	0.38	0.06	29.62
New London	2.55	0.80	2.70	0.93	1.75	6.18	5.28	1.02	2.08	0.40	0.32	†	24.01
St. Cloud	2.75	1.40	4.53	1.56	1.96	6.77	12.81	2.48	4.18	1.69	0.60	0.28	41.01
St. Olaf	1.59	1.52	1.58	1.35	0.77	6.58	4.28	2.44	0.94	1.83	0.22	0.26	23.36
Willmar	1.77	0.65	1.57	0.84	2.01	7.88	5.59	5.25	3.39	0.15	0.10	0.55	29.75

†Trace, when precipitation is less than .01 of an inch.

TABLE CVI.—Continued.

Monthly and Annual Precipitation for the Year 1897.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Southern Section.													
Albert Lea	3.02	0.60	2.70	.....	1.60	3.06	.....	.....	2.41	1.05	0.49	1.25	.....
Bird Island	1.49	0.60	2.04	1.66	1.29	5.43	6.86	1.93	3.08	1.62	0.52	0.05	26.52
Blooming Prairie	1.10	0.04	1.75	1.42	0.95	5.65	9.10	4.00	0.60	1.10	0.35	0.60	27.05
Caledonia	2.48	0.51	1.80	2.32	1.31	5.80	2.79	3.48	1.96	0.32	0.63	0.92	24.32
Camden	2.18	0.49	1.22	3.63	1.39	3.82	4.64	2.99	1.81	0.76	0.75	0.07	23.75
Faribault	1.20	0.45	2.05	1.66	1.11	3.44	6.30	3.96	1.09	1.73	0.40	0.40	23.78
Farmington	1.77	1.35	3.32	2.15	0.85	6.87	4.49	3.44	1.20	2.62	0.80	0.25	29.11
Glencoe	1.21	0.21	2.26	1.44	.....	.....	6.94	3.06	3.87	1.88	0.39	0.12	.....
Grand Meadow	0.85	0.95	0.75	1.64	1.55	6.78	8.05	2.15	0.77	0.85	0.38	0.80	25.52
La Crosse, Wis	1.66	1.39	1.61	1.86	1.50	4.75	1.50	3.47	1.64	0.30	0.75	0.80	21.32
Lake City	0.63	0.95	2.30	0.86	1.83	3.51	4.40	4.20	2.15	1.86	0.29	0.14	23.12
Lakeside	1.30	1.22	1.97	2.50	1.30	9.75	7.35	4.10	2.42	2.29	0.41	†	34.21
Le Sueur	1.80	0.50	3.55	1.97	0.78	6.55	0.80	5.30	0.20	3.35	0.45	0.20	35.45
Lu Verne	1.06	0.25	1.73	2.35	1 56	4.52	6.59	2.17	1.63	2.41	1.00	0.55	25.82
Lynd	.....	.....	.....	.....	.....	.....	4.19	1.94	2.79	0.76	.....	0.10	.....
Mazeppa	0.40	1.70	2.40	0.90	0.70	3.70	4.50	2.70	1.10	.....	.....	.....	.....
Minneapolis—W.B	1.66	1.03	3.05	1.48	1.87	9.00	4.27	1.84	1.57	1.67	0.70	0.13	28.27
" —Vol. 1	1.66	1.05	3.23	1.61	1.92	9.40	4.93	1.84	1.97	1.67	0.97	0.18	30.43
" —Vol. 2	1.58	1.00	3.11	1.52	1.62	9.22	4.70	2.05	1.40	1.71	0.87	0.10	28.88
Minnesota City	2.01	1.00	1.71	2.35	2.90	5.98	4.79	3.46	0.68	0.81	0.53	0.78	27.00
Montevideo	1.68	0.82	2.28	1.91	1.40	4.54	4.09	1.12	1.65	1.10	0.56	0.10	22.13
New Ulm	2.05	1.05	2.29	2.95	0.76	5.49	4.06	2.15	0.33	2.21	0.51	0.29	24.14
Pleasant Mounds	1.57	0.52	1.87	3.54	0.80	4.15	3.64	.....	.....	1.70	0.34	0.59	.....
Rolling Green	1.90	0.95	1.75	4.65	0.60	4.20	3.10	0.90	1.00	1.40	0.20	0.70	21.35
Shakopee	1.55	0.52	2.75	1.19	0.86	6.46	5.46	2 06	1.36	1.82	0.69	0.10	24.83
Spring Park	.....	.....	.....	.....	.....	.....	5.32	2.17	2.07	1.92	0.85	0.08	.....
St. Charles	2.25	1.44	2.15	2.13	1.71	5.18	4.43	3.05	1.01	1.15	0.64	1.00	26.14
St. Paul	2.15	1.03	2.95	1.55	1.81	8.18	6.35	2.18	1.33	1.87	0.93	0.20	30.52
St. Peter	1.15	0.10	2.50	.....	.....	.....	7.32	4.53	2.30	3.32	0.20	0.10	.....
Wabasha	2.08	0.82	1.87	1.47	2.24	4.15	8.55	4.14	1.21	1.27	0.65	0.26	28.71
Worthington	0.62	0.72	1.59	2.82	0.93	6.75	5.55	1.81	2.00	1.82	0.43	0.90	26.02

†Trace, when precipitation is less than .01 of an inch.

The College of Agriculture.

THE FACULTY.

CYRUS NORTHROP, LL. D., *President.*
WILLIAM M. LIGGETT, *Dean.*
SAMUEL B. GREEN, B. S., *Professor of Horticulture.*
OTTO LUGGER, PH. D., *Professor of Entomology.*
HENRY W. BREWSTER, PH. D., *Professor of Mathematics.*
HARRY SNYDER, B. S., *Professor of Agricultural Chemistry.*
T. L. HAECKER, *Professor of Dairy Husbandry.*
M. H. REYNOLDS, M. D., V. M., *Professor of Veterinary Medicine and Surgery.*
WILLET M. HAYS, M. S., *Professor of Agriculture.*
THOMAS SHAW, *Professor of Animal Husbandry.*

NOTE.—The instruction not given by the faculty of the collge of agriculture is given by the faculty of the college of science, literature and the arts.

PURPOSE AND SCOPE.

The college course in agriculture is a thoroughly scientific course emphasizing the sciences of botany, chemistry, physics and geology, and requiring during the freshman and sophomore years at least two terms' work in each of them.

The course naturally divides itself into two parts of two years each, the first part giving but little opportunity for the election of studies, and the latter part making all studies elective.

At the beginning of the third term of the freshmen year the student elects two of the four sciences named as majors and pursues them through the remaining four terms of the freshman and sophomore years. The other two he pursues two terms each, as minors, and thus carries three scientific studies through each of these four terms.

The technical agricultural subjects follow in the junior and senior years, throughout which the student elects as a specialty either one of his major sciences in some of its different forms or some technical agricultural subject with reference to which specialty all other studies are elected.

No classics are required, for the reason that the three modern languages, German, French and Scandinavian, are of more value to the student of scientific agriculture.

The elective studies in the last two years of the course give opportunity for liberal culture in art, literature and philosophy, and for

becoming proficient in scientific research work in some of the many problems pressing for solution in the development of the state and national agricultural experiment stations.

REQUIREMENTS FOR ADMISSION.

Candidates for admission to the freshman class are required to show attainment equal to that represented by the certificate of graduation from the school of agriculture. Graduates of the school of agriculture who have completed the studies required for entrance to this college course are admitted on presentation of their certificates.

Graduates from state high schools may be admitted to the freshman class after spending a year in the school of agriculture pursuing such studies as the faculty may require. Before graduation, all of the work required in the school of agriculture must be completed.

REQUIREMENTS FOR GRADUATION.

After the completion of the prescribed course of study, including all of the required work and the requisite amount of elective work, students will be recommended for graduation with the degree of bachelor of agriculture.

FRESHMAN YEAR.

FIRST TERM.	SECOND TERM.	THIRD TERM.
Drawing, 4.	Drawing, 4.	Chemistry, 4.
English, 4.	Mathematics, 5.	Botany, 4.
Solid Geometry, 4, or Higher Albebra, 5.	Botany, 4. or Zoology, 4.	Zoology, 4. Physics, 4.
German, B. 5.	German, B. 5.	German, B. 4.
Drill, 2.	Drill, 2.	Drill, 2.
Rhetorical Work, 1.	Rhetorical Work, 1.	Rhetorical Work, 1.

SOPHOMORE YEAR.

FIRST TERM.	SECOND TERM.	THIRD TERM.
Botany, 4.	Botany, 4.	Chemistry, 4.
Zoology, 4.	or Zoology, 4.	Physics, 4.
Chemistry, 4.	or Mathematics, 4.	Botany. 4.
German B. 4.	Chemistry, 4.	Zoology, 4.
Physics, 4.	Physics, 4.	German B. 4.
Drill, 2	German B. 4.	Drill, 2.
Rhetorical Work, 1.	Drill, 2.	Rhetorical Work, 1.

In electing from chemistry, physics, botany and zoology the student is required to take the long course in two and the short course in the other two.

JUNIOR YEAR.

FIRST TERM.	SECOND TERM.	THIRD TERM.
Veterinary Science, 4.	Veterinary Science. 4.	Horticulture, 4.
Agricultural Chemistry, 4.	Agricultural Chemistry, 4.	Animal Industry, 4.
Feeding, 4.	Dairying, 4.	Entomology, 4.
Forestry, 4.		Agricultural Chemistry, 4.
Entomology, 4.		Veterinary Science, 4.
		Agricultural Engineer'ng, 4

SENIOR YEAR.

Field Agriculture, 4.	Farm Economics, 4.	Field Agriculture, 4.
Horticulture, 4.	Farm Architecture, 4.	Dairying, 4.
Agricultural Chemistry, 4.	Agricultural Chemistry, 4.	Forestry, 4.
	Veterinary Science, 4.	Veterinary Science, 4.

In the junior and senior years students are required to elect twelve of the above subjects. They are also required to elect an equivalent amount of work from the following list given in the college of science, literature and arts: animal biology, physics, botany, mathematics, English, English literature, geology, minerology, political economy, history, astronomy, pedagogy, psycology, history of philosophy, social philosophy, French, German, Scandinavian. The elective work is subject to the approval of the faculty. Students are advised to continue at least one of the lines of work offered, through the junior and senior years.

COURSES OF INSTRUCTION.

AGRICULTURE.

A portion of the work in agriculture is in the form of lectures. The writing of papers on specialsubjects is made a feature. Research work is arranged for in many cases, and practice work on the farm and in the laboratory is provided. The courses of study are arranged for at such times of the year as will best suit the students in the department. The aim is to have students get experience in field agriculture, both practical and experimental and in demonstration instruction. The work is a continuation of the agricultural studies in the school of agriculture, each subject being here treated from the more technical standpoint.

Course I. Field crops and seeds. Cereals, forage crops, root crops, sugar crops, miscellaneous crops, pastures, meadows.

Course II. Field experimentation and breeding field crops. Where possible practical experience is provided for a portion of the work of this course.

Course III. Agricultural engineering. Selecting farms, deciding upon systems of farming, planning farms, subduing new soils, farm buildings, fences, roads, tillage, irrigation, and implements and machinery.

Course IV. Farm economics. Field management, rotation, weeds, labor, prices, purchases and sales, farm finances, the permanent farm investment, agricultural pedagogics.

Additional courses in special lines may be arranged for upon application.

The University experiment farm, consisting of two hundred and fifty acres of most valuable land, is located between St. Paul and Minneapolis three miles from the campus of the University, and adjoins the state fair grounds. It contains a large variety of soils and exposures and is well adapted to the work of the experiment station and the instruction in agriculture. The farm buildings and the fields are well arranged for experiments and instruction in the various technical agricultural subjects.

AGRICULTURAL CHEMISTRY.

Either two or four terms of chemistry are required, and after completing the required work any of the special courses in agricultural chemistry may be elected.

Course I. In the spring term of the freshman year the subject of general chemistry is pursued. This work is a continuation of the first term's work in chemistry, as given in the school of agriculture. The work consists of lectures and recitations. Remsen's advanced course in chemistry is used as a text-book. Particular attention is given to the study of those elements and compounds which are of the most importance in agriculture.

Course II. In the fall term of the sophomore year the student begins the subject of qualitative analysis. This course is arranged to meet the special wants of agricultural students and is completed the second term of this year. The qualitative analysis of insoluble substances is emphasized. The student spends three two hour periods each week in the laboratory, and one period is devoted to a lecture and a recitation. The students are required to write all of the chemical reactions and to explain the separations involved.

Course III. In the spring term of the sophomore year an elementary course in quantitative analysis is given. This work includes the gravimetric determination of iron, the determination of iron by the bichromate method, the determination of sulphuric anhydrid acidimetry, alkalimetry, the determination of phosphoric anhydrid and of calcium oxide.

Course IV. The chemistry of farm products. Lectures, one term, 4 hours per week. This course relates to the chemistry of production and use of farm products. The ash elements, their importance and functions, and the extent to which they are present in agricultural plants; the organic compounds, found in plants and animals; their functions and uses for food purposes; the chemistry of fermentation, germination, and the factors which influence the growth and composition of farm crops; the composition of human food stuffs, and special topics relating to the chemistry and economy of human foods; and the chemistry of animal nutrition are some of the more important topics which are considered.

Course V. The chemistry of soils and fertilizers. Lectures, one term, 4 hours. This course consists of lectures treating of the various sources of plant food, the forms of food which are the most valuable to growing crops, the amount of food which crops require, and the power which crops possess for obtaining their food from the soil. The subject of soil exhaustion and soil improvement is the basis of this term's work. The size of the soil particles, and their relation to crop production, the composition and characteristics of farm manures, and commercial fertilizers,

the subject of nitrification and the laws which govern the increase and decrease of the soil nitrogen, the organic compounds of the soil and the part which they take in soil fertility are some of the topics which are studied.

Course VI. The analysis of agricultural products. This course consists mainly of laboratory practice, and includes the separation and determination of the various compounds found in plants and animals. Ample facilities are offered in the practical lines of this work inasmuch as numerous chemical analyses are always in progress in the experiment station laboratory. The work includes the analysis of milk, butter, cheese, fodders, grains, milled products, roots and tubers, including sugar beets. The work begins with the determination of the nitrogen, including the pentosans, starches, fats, and other organic compounds. After making these various determinations the student is required to make a complete proximate analysis of some food material. The adulteration of agricultural products, and the methods employed to detect adulteration forms a prominent part of the work. The analysis of water for household, stock, and irrigation purposes is taken up. This course extends through three terms, 4 laboratory periods per week, and is open to all students who have completed the required work in quantitative analysis.

Course VII. The analysis of soils and fertilizers. This course extends through two terms, and includes the study of the methods employed in soil investigations. The chemical analysis of soils and the separation and determination of the various sized soil particles, as sand, fine sand, silt, fine silt, and clay form an important part of the work. Practice is also given in the methods of fertilizer analysis.

Courses VI and VII are intended for those students who wish to make a specialty of the subject.

ANIMAL HUSBANDRY.

Course I. Animal breeding. Under this head lectures are given on the laws which govern breeding. The principles are considered upon which a standard of excellence is based and various standards are compared. Heredity in its various features is discussed, not only with reference to characteristics that are normal, but also with reference to those that are abnormal and acquired. Careful consideration is given to the heridity of diseases. The law of correlation is dwelt upon. Prepotency is discussed especially from the standpoint of practical utility. The good and evil that may result from in-and-in-breeding and line breeding are pointed out. Fecundity and the influences which affect it are examined. The relative influence of parents, the influence of a previous impregnation, intra-uterine influences and those that affect the determination of sex are discussed. The many and far-reaching

influences of nutrition are dwelt upon and quality in live stock, the coat and influences which affect it, and the outcome of artificial conditions generally are gone over with much care. Early maturity, pedigree and animal form as an index of qualities are defined and their great practical value is shown. The art of selection receives special attention. Cross-breeding, grading, the formation of breeds, and the influences of environment are carefully considered.

Course II. Feeding animals. The question of feeding is considered from both the scientific and the practical standpoints. The foundation for succeeding lectures is laid by first considering some important principles which govern feeding. Feeding ratios and nutritive ratios are next discussed and these are followed by lectures on feeding stuffs and the different methods of preparing foods for feeding. Then follows the feeding and management of cattle treated chiefly from the practical standpoint. Lectures are given on rearing calves during the milk period and store animals from the weaning to the finishing period; on finishing for the block on grass, also in the stall; on the selection and care of both males and females of the best breeds, and on stabling suitable for cattle. Similarly the feeding and management of sheep and swine are considered. Careful attention is given to the discussion of wool and its properties and to sheep for wool production, for mutton production, and for both uses combined.

Course III. Pasturing live stock. Lectures are given with reference to the production of pasture other than grass suitable for the various classes of domestic animals kept on the farm. The most approved methods of pasturing these are also discussed. In these lectures every opportunity available is embraced of illustration by direct reference to living animals and an examination of the various kinds of food more commonly used in feeding them.

DAIRY HUSBANDRY.

In the month of January, during the second term of the junior year, students will receive a course of lectures covering the breeding, rearing and management of dairy stock, the points and characteristics essential in animals intended for the dairy, the feeding of dairy cows, co-operative dairying and the manufacture of butter and cheese, with special references for commercial purposes.

During the spring term of the junior year a special study is made of the influence and bearing of the number and size of butter globules and the effects of the other constituents in milk on the efficient creaming of milk and churning of cream; the relation of breeds and types to cost of milk production; field practice work in judging and selecting dairy stock and practice work in ripening cream, churning and packing butter and making cheese especially adapted for domestic manufacture.

ENTOMOLOGY.

The study of entomology will be of a practical nature and only sufficient work will be given in dissecting and classifying insects to enable the students to recognize them as being useful, injurious or indifferent to agriculture and horticulture. The various artificial remedies and insecticides, known to be of benefit will be discussed, as well as natural remedies based upon the life-history of the insects. Injurious and beneficial insects found in Minnesota will be considered, with a view of fighting the former and protecting the latter. The relationship existing between insects and man, between insects and insects, and between insects and plants will be studied in detail. Students wishing to make a special study of economic entomology can find work in the laboratory during the summer, providing they show aptitude for such work and already possess the preliminary training.

HORTICULTURE.

The study of horticulture is embraced under the following courses:

Course I. Fruit growing. Lectures one term. The study of the geography of fruit growing, outlook for fruit growing, planting, tilling and fertilizing of fruit lands; diseases and insects injurious to fruits, spraying; harvesting and marketing of fruit; varieties of fruits.

Course II. Vegetable growing. Lectures one term. Geography of vegetable growing, tilling and fertilizing vegetable lands; irrigation and rotation of crops; seed growing and seed testing; vegetables under glass, pollination; diseases and insects injurious to vegetables and their prevention; harvesting and marketing; varities of vegetables.

Course III. Greenhouses and their management. Lectures and laboratory work; greenhouse instruction and management; temperature, soil, watering, benches; propagation by seeds, cuttings, layers and graftage; diseases and insects injurious to vegetables and their prevention; rest and growth periods of plants; plants for greenhouse cultivation.

Course IV. Nursery work. Lectures and laboratory work. Seedage; layerage; cuttage; graftage; planting; pruning; thinning; storage of nursery stock; tillage of nursery lands; insects, diseases injurious to the nurseries and their prevention.

Course V. Plant breeding, Lectures and laboratory work. The fact and philosophy of variation; crossing of plants; origination of domestic varieties.

FORESTRY.

The study of forestry is included under two courses:

Course I. Lectures. The forestry situation in this country and its literature; lumbering in Minnesota; forest influences; forest supplies; forest management; prairie forestry.

Course II. Lectures and field work. Characteristics of forest and ornamental trees that are hardy in Minnesota; their value for timber and other purposes and methods of propagation.

MATHEMATICS.

Mathematics, as pursued in the college of agriculture, aims primarily at mental discipline and only secondarily at application to lines of practical work.

Algebra, as a means for acquiring fixed attention, penetrating analysis of abstract thought and a comprehensive grasp of logical relations, is required, as given in any standard elementary treatise.

Geometry, as a discipline for clear perception, accurate statement and logical inference, is required, both plane and solid.

Trigonometry is required, both as a mental descipline and for application to practical work in surveying.

VETERINARY MEDICINE AND SURGERY.

The work in this department extends over three terms in the junior year and one term in the senior year. Instruction is given by textbook, lectures, collateral reading and by clinical work in the hospital. The lectures are illustrated by means of skeletons, manikins, charts and by the living animal in actual practice. Anatomy of the digestive organs and the higher physiology of digestion are given prominence in this work.

Theory and practice of medicine are carried further than in the school of agriculture course. Infectious diseases of domestic animals are studied with special reference to causes, recognition, prevention and methods of control. Certain medicines which the intelligent stockman should understand are studied with reference to uses, doses and methods of administration.

Four courses are offered, each covering one term and counting as one credit when finished.

Course I. This is a continuation of last term's work in the school of agriculture and includes an advanced study of the veterinary physiology of digestion, taking up the digestive fluids; digestion of grains and fodders; absorption in general and nervous mechanism of digestion. It also includes a study of body nutrition, body incomes and expenditures, including sources of heat supply and heat loss, and metabolism.

Course II. The muscular system, including general results of contraction, muscle currents, muscle fatigue and laws of muscular work.

The nervous system, including irritability of nerves, electric phenomena of nerves, reflex action, cranial nerves and sympathetic nervous system.

This course also includes the physiology of the skin and nitrogen excreting apparatus: and a study of the locomotor apparatus, in-

cluding shoeing, diagnosis and the treatment of common forms of lameness.

Veterinary Physiology by F. Smith is used as text-book and guide for this work in courses one and two; but students are required to do collateral reading and original investigation.

Course III. This course includes symptoms and recognition of common diseases, common medicines in their doses, uses, dangers and methods of administration. During this course Veterinary Therupeutics and Pharmaceology by Wallace Hoare and Veterinary Medicines by Finlay Dunn are used as text-books and guides.

Course IV. This course includes a study of common diseases of farm stock, as to causes, prevention, diagnosis and treatment.

EQUIPMENT.

LIBRARY.

The library of the college of agriculture contains about four thousand bound volumes, and nearly four thousand pamphlets. The separate libraries of the school of agriculture, experiment station and college of agriculture have all been consolidated, and the consolidated library now forms a part of the general University library. The reports of the various State Boards of Agriculture and Experiment Stations are all kept on file, as well as many of the more important periodicals relating to agriculture. The library is being equipped with the view of making it a reference library for agricultural work. A complete file of some of the more important foreign agricultural periodicals as Versuchs-Stationer, Biedermann's Centasblatt, Annales d l'Societe agronomique, and the Journal of the Royal Agricultural Society of England.

MUSEUM.

The general museum is at present chiefly an agricultural one, containing collections of animals and plants arranged in such a manner as to show their economic relations to the farmer and fruit grower. It is rapidly growing and of great value to the students. The entomological collections of the museum, and Dr. Lugger's private collections are very valuable and contain a very large number of insects of all orders, and all are available for the use of advanced students.

THE FARM STUDENTS' REVIEW.

The Alumni Association of the School of Agriculture is publishing an agricultural paper, the Farm Students' Review, which is now in its third year. This is proving a most important agency in the development of the department and of agriculture in Minnesota.

The School of Agriculture.

FACULTY.

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HENRY WEBB BREWSTER, Ph. D., Principal, *Mathematics.*
SAMUEL B. GREEN, B. S., *Horticulture, Forestry.*
OTTO LUGGER, Ph. D., *Zoology, Entomology.*
CHARLES R. ALDRICH, *Carpentry, Drawing, Farm Buildings.*
FLORENCE A. BREWSTER, *Librarian.*
WILLIAM A. ROBERTSON, B. S., *Physics, Botany.*
J. A. VYE, *Penmanship, Accounts.*
HARRY SNYDER, B. S., *Chemistry.*
T. L. HAECKER, *Dairy Husbandry.*
M. H. REYNOLDS, M. D., V. M., *Physiology, Veterinary Science.*
WILLET M. HAYS, M. S., *Agriculture.*
THOMAS SHAW, *Animal Industry.*
J. M. DREW, *Blacksmithing, Poultry.*
ANDREW BOSS, *Dressing and Curing Meats, Farm Machinery.*
WILLIAM BOSS, *Carpentry, Power Machinery.*
ALVIN D. GAINES, A. M., *Language, Civics, Music.*
HARRY A. LEONHAUSER, Lieutenant U. S. A., *Military Drill.*
E. W. MAHOOD, M. A., *Arithmetic and Athletics.*
JUNIATA L. SHEPPERD, M. A., *Cooking, Laundering.*
MARGARET BLAIR, *Sewing.*
VIRGINIA C. MEREDITH, *Preceptress, Household Art, Social Culture.*

When applying for admission or information, address Dr. Henry W. Brewster, Principal, St. Anthony Park, Minn.

OPENING.

The coming year will open October 3d, 1898, and close March 24, 1899. The fall term closes Friday, December 23d, and the winter term begins Tuesday, January 3d, giving a vacation of ten days. Owing to the shortness of the school year, it is very desirable that students be on hand the first day of the term, that registration may be completed and work begun promptly. Students registered in the fall term will not be received after the first three days of the winter term, unless they shall present a reasonable excuse for such delay.

ADMISSION.

Applicants who have completed a common school course in English grammar, arithmetic, history of the United States and geography,

as prescribed by the state department of public instruction, will be admitted to the regular course without examination.

Students will be credited without examination in subjects for which they can furnish the certificates of high schools.

Applicants who can not complete the common branches at their home district may be admitted to a preparatory class, if they can pass examination in reading, letter writing and arithmetic through fractions, or bring third grade certificates from their county superintendents. But all students who can complete the common branches in their home schools before coming should do so.

PENDERGAST HALL.

Students of mature age, who have but little time for study and who have special needs in the lines of agriculture, stock and farm engineering, will be registered for special work during the winter term as indicated in the daily program. Such students will be required to pay a registration fee of $5 and to board themselves outside of the

institution. It is better for such students to buy the few books they may need than to rent them.

Applicants for admission after the opening of the term will, in addition to the regular entrance examinations, be required to show proficiency in the work done by the class up to the time of their application. All who cannot enter by the middle of November should wait until the beginning of the winter term.

EXPENSES.

The cost to the students, for board and washing, is the actual cost of maintaining the table and caring for the house. This does not exceed $3.00 per week. A month's board is assessed in advance for the purchase of provisions at cash prices. At the end of the month the exact cost is calculated and the proper deduction made from the next assessment. The culinary department is managed by an experienced matron, and all the buildings are under the supervision of the principal. The buildings are illuminated with electric lights, and warmed by steam: the sleeping rooms are each furnished with a bedstead, mattress, dressing bureau and table.

Each student furnishes four sheets, one pair of blankets, one quilt, one bedspread, one pillow, three pillow cases, two bath towels, comb and brush.

No deductions in charges are made for absence of less than four days. If students are compelled to be absent for that length of time they will be allowed half rates, if they arrange with the matron before leaving. Students wishing to retain their rooms after vacation, must be on hand when the second term opens, or pay one-half the price of board and room for the time they are late.

Students who do not engage rooms in advance, may be forced to find sleeping rooms elsewhere at an additional cost of fifty cents per week.

Text books are furnished, at an annual rental of $2, to students who do not desire to purchase.

Drawing tools may be had at a rental of twenty-five cents per term, or may be purchased for about $3. Drawing materials and mimeograph lectures are furnished to the students at cost.

Military drill and uniform—All students taking the drill are requested to provide themselves with the uniform, which consists of blouse, trousers, vest and cap, modeled after the U. S. Military Academy uniform, of cadet gray, and is as neat and economical a dress as the student can obtain. The leading furnishers of Minneapolis and St. Paul furnish the suit complete, to measure, for about $17. The vest may be omitted, for which allow $3. A much cheaper uniform than the above can be obtained, but is not recommended.

Fees—Students pay an incidental fee of $1.25 per term, and also pay for breakages of apparatus used in practical work. In chemistry

there is a small fee, about fifty cents, to cover the cost of material used.

Deposit—In addition to the assessment of $12 for board, at the beginning of the term, a deposit of $5 is required of each student as a guaranty for the return of all books, tools and other articles borrowed.

The total expenses for the year need not exceed $85 to each student.

GRADUATION.

Students are entitled to the certificate of the University upon the following conditions:

First—The completion of the prescribed course with an honorable standing in deportment, and thoroughness and intelligence in subjects studied.

Second—A practical experience in field work, either at the University or elsewhere, as shall appear in reports received from responsible sources.

Third—The completion of an essay, of about one thousand words, upon some subject connected with farming.

This certificate, with a certificate in mathematics, admits students to any one of the special lines of study provided in the college of agriculture.

STUDENTS' DEBATING SOCIETY.

A society for the purpose of improvement in elocution and debate, and for obtaining instruction, in the form of lectures, gives excellent opportunities for entertainment and culture.

STUDENTS' CHRISTIAN ASSOCIATION.

This society has for its object the study of moral and religious subjects, and the holding of regular weekly prayer meetings and conference meetings. All students, regardless of creeds, are welcomed to membership; no sectarian differences are allowed to be discussed in the meetings or in the reading rooms.

The young Men's Christian Association of the school will station several of their members at the depots to meet and direct incoming students on the arrival of the trains, Monday and Tuesday, October 3 and 4. One member bearing a badge lettered "Y. M. C. A., S. A. U. M.," will be at each of the following depots: Great Northern, in St. Anthony Park; Union, in St. Paul; and Union, Milwaukee and St. Louis, in Minneapolis.

ATHLETIC ASSOCIATION.

The students have a well organized athletic association and a well equipped gymnasium. A competent instructor is in charge each evening. An opportunity is thus given for healthful amusement and for needed physical exercise.

The first building erected upon the campus has been remodeled and furnished for a home for the young men. It contains on the first floor the library, a large reading room supplied with good reading,

and parlor games; a general sitting room; also a parlor in which students receive visits from friends. In the basement are rooms specially adapted for change from recitation rooms into dining rooms for class parties, which enable students to learn the art of receiving and entertaing company.

THE HOME.

The building for young women contains a large sitting room for general use, a parlor for more special use, rooms for the preceptress, and thirty suites of rooms for sixty students, each suite consisting of a study room for two with two alcove sleeping rooms adjoining.

This gives each student a separate sleeping room, a study room for herself and one mate, the free use of sitting room and parlor in the girls' home, and the benefit of slass parties in the Home Building.

In the large sitting room there are papers, magazines, books and a piano, which afford pleasant recreation.

LIBRARY.

The library contains four thousand books of reference, besides nearly four thousand pamphlets, including reports, bulletins, etc.

The library is supplied with a card catalogue from the United States Department of Agriculture, of all reports and bulletins issued by the different experiment stations. This enables one to find some reference on nearly every agricultural subject. In connection with the library is the reading room, where all the leading agricultural papers, as well as other leading periodicals, are kept on file for the use of the students.

Quite a number of the instructors have written text books in their own lines of work, and are using them in the lecture rooms.

COURSE OF STUDY.

FIRST YEAR.

FIRST TERM.

Agriculture [3].

Botany [5].

2 Drawing [2].

2 Music or Athletics [1].

Physiology [5].

Study of Breeds [3].

2 Blacksmithing [1].
2 Carpentry [2].
Carpentry, Lecture [1].
2 Military Drill [1].

or

2 Laundering [2].
2 Physical Culture [1].
2 Sewing [3].
2 Social Culture [1].

SECOND TERM.

Botany [5].

2 Farm Accounts [2½].

2 Music or Athletics [1].

Physiology [4].

2 Carpentry [2].
Carpentry, Lectures [1].
2 Farm Buildings [2].
3 Blacksmithing [1].
2 Military Drill [1].

or

2 Cooking [3].
2 Drawing [2].
2 Home Management [1].
2 Physical Culture [1].

SECOND YEAR.

FIRST TERM.

Dairy Chemistry [2].

2 Dairy Husbandry [2½].

Fruit Growing [3].

2 Music or Athletics [1].

Zoology and Entomology [5].

2 Breeding [2½].
2 Military Drill [1]
Physics [5].

or

2 Cooking [3].
2 Household Art [1].
2 Physical Culture [1].
2 Sewing [3].

COURSE OF STUDY—*Continued.*

SECOND YEAR.

SECOND TERM.

2 Agricultural Chemistry [5].
2 Dairy Husbandry [2½].
2 Music or Athletics [1].
Physics [5].
Vegetable Gardening [3].
Poultry [1].

Field Crops [5].
2 Military Drill [1].
} or {
2 Cooking [3].
2 Home Economy [2].
2 Physical Culture [1].

THIRD YEAR.

FIRST TERM.

2 Agricultural Chemistry [5].
Forestry [3].
2 Music or Athletics [1].
Plane Geometry [5].

2 Handling Grain and Machinery [1].
2 Veterinary Science [3]
} or {
2 Sewing [4].

SECOND TERM.

Civics [4].
2 Dressing and Curing Meats [1].
Plant Propagation [3].

Feeding [3].
Soils and Fertilizers [5].
2 Veterinary Science [3].
} or {
2 Cooking [3½].
Domestic Chemistry [3].
Domestic Hygiene [2].
2 Sewing [2½].

1. Students who decide to take the college course in agriculture must complete *elementary algebra*. Any one of the following authors will furnish the necessary preparation: Ray, Greenleaf, Wells, Sensenig, Thompson and Quinby, Wentworth (school), Taylor (academic), Milne (high school), Stringham-Smith, Collins. If Olney's complete Algebra or Wentworth's Elements of Algebra be used, selections may be made equivalent to the above.

Plane Geometry—Olney's text book, or equivalent, including the unsolved problems.

2. Figures in brackets indicate the number of hours per week in which the subject is pursued; all work in subjects marked thus 2, extend through double time in the daily program.

One essay and one declamation is required of each student in each term of the first two years. Those taking the regular work in the literary societies will be excused from the declamation.

PROGRAM—FALL TERM 1898.

INSTRUCTOR	8:15-9:00	9:05-9:50	9.55 10:40	10:45-11:30	11:40	1:15-2:00	2.05-2:50	2:55-3:40	3:45-4:30	4:35
Aldrich						C. I. Drawing, 4 Pds	F. H. Drawing, 3.	C. II. Drawing, 4 Pds.		
Blair						B. Sewing, 2, 4. C. Sewing. 1, 3. 5.		B. Sewing, 2. A. Sewing. 1, 3. 4, 5.		
Boss, A							A. Handling Grain & Machin'ry, 3 Ps			
Boss, W.		A. Power Machinery. 1.				C. I. Carpentry. 5 Pds.		C. II. Carpentry, 5 Pds.		
Brewster,	A. P. Geom. A. R.	Algebra, S. W. R.					U. Solid Geometry.			
Drew						C. II, Blksmithing, 2 Pds		C. I Bl'ksmithing, 2 Pds		
Gaines		I. Language A. R.	III, L'n g'ge A. R.	II. Langu'ge A. R.	C					Music. 2 Pds
Green			B. Fruit Cul 1, 2, 3.	A. Forestry 1, 2, 3.						
Haecker					H	Farm Dairying. 1, 5.	B. I. Home Dairying, 3 Pds. 1. B. II. Home Dairying, 3 Pds. 3. B. III. Home Dairying, 3 Pds. 5.			
Hays		C. I. Agric. 1. 2. 3	C. II. Agric. 1, 2, 3.		A					
Jacobson										Physical C'lture, 2 Ps
Leonhauser					P					Mil Drill 2 Pds.
Lugger		B Ent'm'gy & Zoology			B					
Mahood		II. Arith. S. R.	I. Arith. S. R.	III. Arith. S. R.						Athletics, 2 Pds.
Meredith.	B. H'schold Art, 1, 2. Social Cul. 5	C. Social Culture 5			L					
Reynolds			C. I. Physiolog 1.	C. II. Physiology.				A. Veterinary Science, W'dn'sd'y & Frid'y. 5 Ps		
Robertson	C. I. Botany	C. II. Bot'ny		B. Physics.						
Shaw			C. I. Study of Breeds, 1, 2			B. B'rding 2, 3, 4.			C. I. Study of Br'ds, 1 Pd 3	
Shepperd								B. Cooking, 3, 4. Laundering, 1, 2.		
Snyder			B. Dairy, Chemistry 4. 5, 2 Pds.			A. Agr'l Chem. 10 Pds.				
Vye		Pnmanship						C. I. Acc'nts, 3, 4, 5; 5 Pds.		
Wilson							Reading I.	Reading II.		

PROGRAM—WINTER TERM 1899.

INSTRUCTOR	8:15-9:00	9:05-9.50	9:55-10.40	10:45-11:30	11:40	1:15-2:00	2:05-2:50	2:55-3:40	3:45-4:30	4:35.
Aldrich			Special Drawing, 3.			C.I. Drawing, Free Hand Drawing, 3.		C. II. Drawing,		
Blair						A. Sewing, 3.		A. Sewing, 2.		
Boss, A							A. Dress'g & Cur'g M'ts, 1			
Boss, W			Special Carpentry, M. Sp Power Machinery, 1, 2			C. I. Carpentry.		C. II. Carpentry.		
Brewster	Algebra	Geometry 2, 3, 4, 5.								
Drew			Spec. Bl'k Sm'ing, 4, 5. B. Poult. I			C. II. Blacksmithing.		C. I. Blacksmithing.		
Gaines	P. I, Language.	A. Civics 2, 3, 4, 5.	P. II Language. B. Veg. Gar. 2, 3, 4.	P. III. Language. Plant Prop. 2, 3.	C					A. Music. 2 Periods.
Green								A. Plant Propagation, 5		
Haecker					H	B. Dairy Stock, 1, 5.	B. I. Home Dairying, 1. B. II. Home Dairying, 3. B. III. Home Dairying, 5.			
Hays	B. Field Crops.	C. II. Agr. 1, 2, 3.			A					
Jacobson										Physical Culture, 1, 4
Leonhauser					P				Mil. Drill.	2 Periods.
Mahood		P. I. Arith.	P.III. Arith.	P. II. Arith.	E				Athletics,	2 Periods.
Meredith	B. Home Ec'n'my, 1, 2		A. Domestic Hygiene, 1, 2				C. Home Managem't, 5.			
Reynolds			C. I. Physiology. 1, 2, 3, 4.	C. II. Physiology. 1, 2, 3, 4.	L		A. Veterinary Science, 2, 4			
Robertson	C.II. Bot'ny	C. I. Botany		B. Physics.						
Shaw	A. Fdg. 3, 4, 5 Sp. Sk, M 1, 2	C. II. Study of Br'ds, 4, 5							Study of Breeds, 3.	
Shepperd						A. Cooking, 2, 3, 5.		B. Cooking, 2, 3, 5. C. Cooking, 1, 4.		
Snyder	A. Domestic Chem. 3, 4, 5.	B. Ag. Chem	A. Soils & F							
Vye	P.II. & P.III P'nmanship							C. II. Accounts, 2, 4, 5.		
Wilson	Algebra.	Sp. Arith M 1, 2 Sp. Lang, 3, 4, 5					History.	History.		

SPECIAL ELECTIVE WORK.

Graduates, and others of equal attainments, are offered the opportunity of entering as special students the elective work in mathematics, English composition, farm buildings, and such lines of pracitcal work as they can individually arrange to prosecute with the instructors in charge of such lines.

Each special student is expected to elect at least three lines of work and do an amount of work in these lines that shall be satisfactory to the instructors in charge.

Any contemplating this elective work should make application to the principal before coming, and should state what lines of work they desire to pursue.

SPECIAL STUDENTS.

Special students, who do not find a sufficient amount of work in the various lines of lectures and practice work, in either the fall or winter term, will be assigned by the registration committee to class work in agriculture. Such work may be assigned in agriculture for the first period, and in stock for the second period.

CONNECTION WITH THE COLLEGE COURSE.

The school articulates with the College of Agriculture, in which the subjects are largely elective to meet the demands for special education.

CHARACTER OF INSTRUCTION.

AGRICULTURE.

The instruction in agriculture continues through the course and is outlined as follows:

The selection and general management of farms, soils and soil formation; drainage: tillage; road making and fence building will be taught. The production of grains and grasses; clovers and other forage plants; the management of grass lands; the rotation of crops and the management of fields in relation to fertility, to weeds, to live stock and to profits, are considered. Many special subjects, such as breeding field crops, stacking grain, handling machinery, and exterminating noxious weeds, are dealt with. Green manuring, management of farm manures and the place of commercial fertilizers in field management in various parts of the state are discussed.

University Experment Farm is conducted partly with reference to instruction. A number of students are engaged each summer to assist in the experimental work with field crops and field management, also the preservation of crops in silos and other ways. Many conveniences on the farm serve as models of their kind. A museum of a limited number of the best modern farm machines is maintained.

AGRICULTURAL CHEMISTRY.

The first term is devoted to the study of the general principles of the science of chemistry, particular attention being given to those elements and compounds which are the food of plants and animals. This work is illustrated by the many chemical changes which take place on the farm; the student spends a part of his time in the laboratory performing experiments which relate to the subjects which are studied in the class-room.

In the second term the chemistry of farm products is begun. The composition of human and animal food stuffs forms an important part of this term's work. The chemical changes which take place during the growth of crops are studied, as well as the various factors which influence the food value of agricultural products. During this term one period each day is given to a class-room exercise and one period is spent in laboratory work. In the laboratory, the student separates the various compounds of which food stuffs are composed, and he also studies the various types of food materials.

One term is given to the chemistry of soils and fertilizers. The requirements of the various farm crops in the way of food, and the best ways of satisfying these demands are considered. The various forms of plant food which exist in the soil, the chemical changes which the plant food undergoes, and the power of crops to make use of the various compounds of the soil, form important parts of this work. In the study of soils and fertilizers it is the aim to study the principles which govern the maintenance of the fertility of the soil.

In the chemistry of dairying, instruction is given in the chemical and allied changes which take place in the handling of milk and in its manufacture into butter and cheese.

ALGEBRA.

No algebra is required. Students intending to enter the college of agriculture, after graduating from the school of agriculture, should complete elementary algebra. (See foot note I. course of study.)

ANIMAL INDUSTRY.

The talks on animal industry will be most practical. The characteristics of the leading pedigreed breeds that have special adaptation to northwestern conditions, will be discussed. The points of good and inferior animals in beef-cattle, sheep and swine will be so taught that the student may learn to choose wisely when selecting foundation animals from which to breed, or animals to prepare for the block. The fundamental principles that govern breeding, will be pointed out in the simplest manner possible. The feeding of animals will be discussed, special prominence will be given to the choice of foods for live stock at the different stages of their development and to the preparation of the same for breeding. The general principles which relate to the care and management of cattle, sheep and swine will be made clear. And, as far as practical, these talks will be illustrated

by the presence of the living specimens of the various animals under discussion.

ARITHMETIC.

Students entering the preparatory class in arithmetic are required to understand arithmetic through fractions, both common and decimal. The course gives special attention to denominate numbers, percentage in its various forms, interest, discount, evolution and mensuration. The aim is to secure both accuracy and facility in the most practical operations.

BLACKSMITHING.

The students are instructed in the management of the forge and fire, and in bending, shaping and welding iron and steel. They are required to make links, rings, hooks, bolts, clevises, whiffletree-irons, tongs, cold chisels, punches: in short to become familiar with all the operations necessary to enable them to do their own repair work when they return to the farm. Particular attention is given to rapid and accurate welding, and to the shaping and tempering of steel tools. The forges used are such as any farmer can make for himself, and each student is taught to make his own tools, so that he will be able to furnish his shop with very little outlay.

BOTANY.

This study is taught with special reference to its bearing upon the every-day problems that present themselves to the farmer and gardener. It is profusely illustrated with flowers and plants from the greenhouse and nursery. Some instruction is given in the use of the compound microscope; students are thus enabled to study intelligently, in an elementary way, the tissues of plants. By this means they get a clear idea of the general principles of plant structure and vegetable physiology.

CARPENTRY.

Instruction is given by means of text-books, lectures, and work in the shop and drawing room, in the care and use of tools, including setting and filing saws, filing bits, grinding plane-irons, chisels and other tools; also in laying out work and framing buildings. Methods of construction are illustrated by models and drawings. Various articles for use about the farm are manufactured by the students.

CIVICS.

During the last term of the course, students receive instruction in this science, and graduate with a good understanding of the origin, necessity, nature and various forms of government and the machinery employed to carry on public works, establish justice, and provide for the common defense; of the organization and management of local institutions, the town, the village, the city and the county; the manner in which states are created and their affairs administered; the three departments, legislative, judicial and executive, and the functions of

each; the interdependence of the state and its citizens, as well as the powers and obligations of each, by due attention to which the state may be strengthened and the condition of its citizens ameliorated.

The relation of the States to the general government; the constitution and the powers it confers, and the provisions for amendments are taught. The more important principles of commercial law, including contracts, agency, partnership, corporations and commercial paper, receive attention. Instruction is also given in the United States method of surveying public lands.

COOKING.

The course in cooking extends through four terms of the curriculum as given below with the subjects covered in each term.

Second term C year—Kitchen management; care of cooking utensils, glass, china and silverware; measuring and invoicing; cooking vegetables, cereals and breads.

THE DRILL HALL.

First term B year—Canning, preserving, pickling and jelly making; soups, eggs and meats.

Second term B year—Marketing, care of foods and cold storage; fruits, salads, hashes, croquettes, "save all" dishes and lunch baskets; equipment of dining room and table service.

Second term A year—Food rations, dietaries and bills of fare; invalid cooking, beverages, frozen dishes, pastry and cake; food economics, table duties of host and hostess and essays on housekeeping.

DAIRY HUSBANDRY.

Dairy Stock--During the first term and the last part of the second term of the second year, students receive instruction in the characteristics of the various breeds of dairy stock, with practice in judging by the score card, the breeding, rearing, feeding and management of dairy cattle.

Home Dairying—Practical work in this branch commences the second week of the first term, and closes the second week in December, and during the second term it commences the second week in January and continues until the close of the school year. Students receive practical training in the most advanced methods of handling and testing milk, creaming milk, by the gravity and centrifugal process, ripening cream, churning, working and packing butter.

DOMESTIC CHEMISTRY.

In domestic chemistry instruction is given in the chemistry and economy of human foods. Simple tests for the detection of the adulteration of foods are given. The chemistry of cleaning material, and the composition of various household articles are considered. The instruction is given in the form of laboratory practice.

DRAWING.

The student is taught the practical value of drawing for the purpose of designing and arranging buildings, machinery, etc. He makes drawings of the shop exercises then works from his own drawing thereby learning the application.

Designs are made for dwellings, barns, out-buildings, and machinery. As practical subjects for their designs, students are requested to bring from home data for plans of buildings needed on their farm. Estimates are made of the amounts of materials required and cost of construction.

Special students are offered advanced work in designing, including style, stability, convenience and economy of arrangement of buildings and machinery for various purposes.

DRESSING AND CUTTING MEATS.

Instruction is given in a course of lectures and demonstrations.

Two weeks' practice work in dressing and cutting up beef, pork, mutton, veal and poultry is required of each student before graduation.

ENTOMOLOGY.

The class in entomology receives instruction of a practical nature. The course is divided as follows:

Classification of insects, sufficient to enable the student to distinguish between useful and injurious insects and to apply remedies intelligently, as the remedies must be selected according to the kind of insect to be combatted.

Insecticides and their application; the most approved methods of

using arsenical poisons, kerosene emulsions, pyrethrum, and other preparations are taught.

Natural remedies and nature's methods of preventing increase of injurious insects receive due attention so as to enable the student to apply their teachings. The relation of other animals to insects is also taught, so that the student may know both his friends and his foes. Special attention is given to injurious and useful insects of Minnesota.

GEOMETRY.

The first two books of Wentworth are required. Students intending to enter the college of agriculture should finish plane geometry. Special attention is given to principles of symmetry, clearness of statement, and accuracy of logical inference.

HOME ECONOMY

Is taught as the just proportion between income and expenditure; the distinction of economy, frugality and parsimony are considered with reference to a definite proportion in the expenditures which are made for existence, comfort, culture and philanthropy. A study is made of the sources of income, especially of the income from the farm in the form of house, food and luxuries. The purchase of clothing, household stores and furnishings is considered from the standpoint of the suitable. The relation of cash and credit to cost is also considered. Attention is given to savings and forms of investment, a bank account and the use of a check book. Each student in this class is required to submit at the close of the term a paper setting forth in detail the use of a certain named income for one year, embracing not only every item of necessary home expense but also an outlay made for travel, luxuries, accident, sickness and other emergencies. The habit of keeping a household account is calculated to strengthen the judgment in making a wise use of money, therefore an analysis and study of expenditures as here indicated serves to bring clearly before the student's mind the relative importance of the different things which money will procure.

HOME MANAGEMENT

Includes both housekeeping and home making and the teaching of the subject naturally falls into three divisions, household work, sanitation and family life. The instruction is based upon the belief that housekeeping is as important as it is difficult—and that home making is the noblest form of human endeavor. The points in detail in the preparation of food, the making of clothing, the care of the house and household belongings, and the ordering of the family life are considered in their relation to an adequate plan for home management. To start the student in the correct way of becoming mistress of the business of housekeeping is the end sought. It is believed that for one who knows the reason for the doing there is no drudgery, therefore students are taught the specific danger that lurks in dust and dirt, in

order that they may understand the dignity of the unceasing war which the housekeeper makes upon those forces. The practical benefit to be derived from the knowledge students have gained in the cooking, sewing, laundering and dairy class is emphasized and shown in its relation to an adequate plan for the daily program for the home. While the science of family life has not been formulated yet some of its fundamental principles are recognized and may be taught.

HORTICULTURE AND FORESTRY.

Fruit growing is taught with reference to raising fruit for market.

Vegetable gardening embraces the study of garden tillage, irrigation and rotation of crops; transplanting; formation and care of hotbeds; study of garden insects and the growing of various vegetable crops.

Plant propagation—In this subject the principles underlying the development of cultivated varieties of plants and seed testing are taught; also the propagation of plants by seed. cuttings, grafting and budding.

Forestry includes the consideration of the formation and care of wind breaks and shelter belts, the laying out and planting of home grounds; discussion of the hardiness, habits and value of our native and introduced trees; and the methods of propagating them.

The work of the class room is illustrated by the orchards, nurseries, forest plantations, gardens and greenhouses on the grounds of the experiment station and by visits to commercial nurseries and greenhouses near by.

HOUSEHOLD ART

Is taught by a series of lectures treating of the adornment of the house and grounds, noting the distinctive character of the country home and the opportunity for embellishment found in the surroundings. The intention is to show that thought and energy can accomplish as much or more than money in making a farm house attractive; also to show the importance of acquiring correct knowledge and correct taste in order to secure every possible convenience, combined with harmonious forms, colors and styles in walls, draperies and furniture. The true relation of beauty and use and the influence of surroundings upon life and character are considered in connection with the possibilities for improvement that may be found in simple and inexpensive methods.

HYGIENE

As a special study for women, considers the health of the family as dependent upon pure food, pure water, personal cleanliness and proper habits, as well as upon heredity. The aim is to show how a correct knowledge of the laws of nature is essential not only to the restoration but to the preservation of health.

Several lectures by a physician will be given upon maidenhood, maternity, motherhood, infancy and related subjects. These special lectures will be supplemented by the regular lectures in class, thus

extending and simplifying the subjects in plain and easily understood terms.

LANGUAGE.

The work in language aims to secure the use of proper words and correct forms of expression in conversation, letter-writing and the more extended forms of composition. The student is led to think, to analyze and define his thought, to choose words that will accurately express it, and to arrange these words in harmony with the rules of grammar, the forms of correspondence and the elementary principles of rhetoric. Attention is given to the sounds of letters as indicated by their markings; the meaning of prefixes, root syllables and suffixes; classification, inflection and the syntax of simple, complex and compound sentences; the nature and correction of common errors; practice in letter-writing and descriptive composition.

One essay of about five hundred words is written, submitted for criticism, corrected and re-written during the first two months of each term of the first two years of the course.

This analytic method naturally leads to the study of not only the dictionary, the grammar and the rhetoric, but also of authors, speakers, periodicals and all good authorities on language.

LAUNDERING.

In the first term of the C year several lectures are given and practice work is provided in washing, ironing, starching, polishing, cleaning and pressing clothing.

MUSIC.

Classes in music will be organized for students who desire training in this branch.

PENMANSHIP AND ACCOUNTS.

In this department the student is taught to write a plain hand with rapidity and ease. The work in accounts is applied to the transactions which the student meets in the various duties on the farm. He is so taught to keep his accounts that he may know at any time the profit or loss of any department of his business, and is thus enabled to plan intelligently.

Attention is given to the different kinds of negotiable paper; the various forms of endorsements and their effect; business forms and correspondence. Everything is made plain and practical, and students can learn to keep accurately and neatly the accounts of an ordinary business.

PHYSICAL CULTURE.

The work in this department is particularly directed to the improvement of nutrition and the correction of faulty habits of carriage and posture, frequently the result of exercise taken in the performance of household tasks which have a tendency to produce overdevelopment of certain muscles, while leaving others almost unused. The

course of study includes free gymnastics and the use of light apparatus, supplemented by movements taken from the Delsarte system of expression.

There are two classes, one for elementary and the other for advanced work.

PHYSICS.

The general principles of the science are taught, special stress being laid upon those which to the greatest extent enter into the business of the farmer. About half the time is devoted to experimental work, which includes capillarity of soil; diffusion and osmosis of gases and liquids; heating, lighting and ventilation; farm machinery in particular, pumps, eveners—especially three and four-horse—pulleys, milk testers, centrifugals, incubators, windmills, steam and gasoline engines; friction and lubricants; tensile strength of wire and binding twine of different grades: lightning and lightning protection. The foregoing indicates the character of the work, the attempt being to give the student the acquaintance with the laws of nature that he may act with reason and work to advantage.

PHYSIOLOGY.

During the first year the students take a high school course in human physiology and hygiene. In this course, they study the general plan and structure of the body and the tissues of which the body is composed; then the skeleton, muscles and body nutrition. Body nutrition includes a study of foods, digestive organs and fluids, and processes of digestion.

The class then studies in succession, circulation and respiration, including ventilation, respiratory apparatus, kidneys, skin, nervous system, senses, voice and narcotics, including alcohol, opium, morphine, chloral, cocaine and tobacco.

This class work is illustrated by means of large charts, skeletons, manikins and dissections. Important points of difference between human and animal physiology are pointed out in preparation for the next year's work in the veterinary class. Matters of home and personal hygiene are interwoven with the physiology work.

POULTRY.

In the instruction in this subject, the following will be considered: History and characteristics of the leading breeds of poultry; breeding, feeding and management of fowls for eggs and for the market; planning, building and arrangement of poultry houses; managing incubators and brooders. A model poultry house, containing pens of the most improved breeds, incubator cellar, workroom, etc., has been provided, where experimental work and practical instruction will be carried on.

POWER MACHINERY.

Special students of mature years who desire to become proficient in the management and care of stationary engines and boilers, or

threshing engines either steam or gasoline, will be given a chance to pursue special work in the care and management of such machinery. Instruction will be given by means of lectures and practical work in the engine room. Boilers, engines, injectors, pipe fitting, wind mills, well pumps, hydraulic rams, etc., will receive special attention.

SEWING.

During the first year students receive instruction in the elements of sewing; different stitches, such as basting, seaming, hemming, darning, buttonholing and patching are taught: and practice is given in the use of all the implements belonging to the sewing basket.

The second year's work consists of cutting and making plain garments such as underwear, children's clothing, shirt waists and cotton dresses.

In the third year the more difficult work of dressmaking is taken up. The cutting and fitting of dresses and jackets is taught by a very simple system: careful attention is given to quality of materials and harmony of colors. The course is designed to make each graduate capable of doing all kinds of sewing needed in the home.

SANITATION.

This work includes a general study of home hygiene and deals with water for the house, drainage and ventilation, together with a study of some diseases that may be associated with these factors. The study of water includes quantity, collection, quality, storage and the origin of impurities. Under the subject of ventilation, there is considered quantity of air per individual; natural and artificial ventilation. The study of clothing includes a study of the materials of which it is made, their various heat-retaining qualities and a study of clothing according to climate in which the individual lives. This study of home hygiene will also include the prevention of disease in general and the prevention, in detail, of certain common diseases, as consumption, diphtheria, scarlet fever and colds. The selection of a site for a home is a very important matter and will be given due consideration as well as the proper care of the home after it is built.

SOCIAL CULTURE.

A course of lectures is given on the usages of good society, including manners, good behavior, the voice, conversation, forms of address, invitations, etc. Attention is directed to the fact that all approved etiquette rests upon the great law of kindness. The importance is shown of personal fitness for society through attention to the laws of health and to personal habits as well as through the refinement of a cultivated mind and sympathetic spirit. Suggestions are made in reference to reading, literary taste and the choice of books. Especial stress is put on the thought that the family life ought to be the highest expression of good society and therefore the manners and conversation in the home should be the very best of

which one is capable Next in importance to the power of thinking correctly is the power of approaching others with ease and speaking with tactful directness and consequently any study or practice intended to cultivate the social nature deserves earnest attention. Some instruction is given in the elementary principles of parliamentary usage.

VETERINARY SCIENCE.

During the A year, the students take up a course of study in veterinary medicine, the purpose of which is to fit them for intelligent care of their farm stock and not to make them in any sense professional veterinarians. In this course the teaching is done by means of lectures, distribution of mimeographed lecture notes after each lecture, reviews and clinical work at the hospital maintained for this purpose. Lectures are illustrated by means of charts, manikin of horse, skeleton of horse, and various other appliances.

The lecture course consists of a series on each of the following subjects: Elementary anatomy, elementary pathology, causes and prevention of diseases, diagnosis and treatment of common diseases and a final short course on common medicines, studying their effects, uses and doses. At the hospital clinics, students are enabled to examine and care for a variety of cases and to learn the elements of diagnosis for the more common diseases and forms of lameness.

ZOÖLOGY.

Chiefly Minnesota animals are considered: (1) their classification: (2) their habits and food: (3) their relation to the farmer. To assist the students in their work a museum has been started in which is shown the relation of Minnesota animals, birds, reptiles, etc., to agriculture. Soils, minerals, fossils, plants—both useful and injurious—are also on exhibition.

DAIRY SCHOOL.

SPECIAL ANNOUNCEMENT

FOR THE

TERM BEGINNING JANUARY 3, 1899.

THE FACULTY.

CYRUS NORTHROP, LL. D., *President.*
WILLIAM M. LIGGETT, *Dean.*
T. L. HAECKER, *Professor of Dairy Husbandry, in charge of School.*
HARRY SNYDER, B. S., *Dairy Chemistry.*
OTTO LUGGER, Ph. D., *Bacteria in Dairy Products.*
W. M. HAYS, M. S., *Forage and Pastures.*
M. H. REYNOLDS, M. D., V. M., *Diseases of the Dairy Cow.*
J. A. VYE, *Creamery Records and Accounts.*
WM. ROBERTSON, B. S., *Care of Boiler and Engine.*
C. R. ALDRICH, *Dairy Buildings.*
J. M. DREW, *Silo and Stable Conveniences.*
B. D. WHITE, *Instructor in Butter Making.*
A. J. GLOVER, *Instructor in Cheese Making.*
WM. BOSS, *Instructor in Practical Engineering.*
E. W. MAJOR, *Instructor in Sweet Curd Cheese Work.*
N. H. FULTON, *Assistant in Creamery.*
L. R. HOBART, *Assistant in Creamery.*
H. C. HAECKER, *Instructor in Dairy Lab ratory.*

The next session of the Dairy School will begin January 3, 1899. and continue four weeks.

This course is designed to furnish persons who are actually engaged in the manufacture of butter and cheese, or who purpose to take up this work, an opportunity to become more skilled in their work, and also to study the many problems which have a direct bearing upon the dairy industry. Recognizing the fact that such persons cannot be away from business for a long period, the term has been so arranged that the time of each student is fully occupied by lectures and actual work every hour of every working day of the term.

The rapid growth of the dairy industry in the Northwest calls for a corresponding enlargement of the work in dairy instruction. To meet this want, the dairy hall has been more than doubled in capacity

and equipped with all apparatus necessary to give instruction in the various lines of dairy work.

No pains will be spared to maintain the high standard which the school has attained. Each member of the faculty has special qualifications for the duties to which he has been assigned. The lecture course and practical instruction are arranged with special reference

(DAIRY HALL.)

to giving the greatest amount of training and practice possible, in a four weeks' session. Large additions have been made to the equipment of the dairy hall in both butter and cheese departments; in fact, it has everything needed for conducting work by the most approved methods.

Instruction is divided into six courses:

I. Lectures covering the entire field of dairy husbandry.

II. Practical work daily in the butter room.

III. Practical work daily in the cheese room, where the manufacture of flats, cheddars, Swiss, brick, Edam and Gouda cheese will be carried on.

IV. Practice work in the laboratory, examining milks, making daily composite tests, and the pasteurization of milk and cream.

V. Practical engineering, steam-fitting and plumbing.

VI. Practical work in factory bookkeeping.

I.—LECTURES.

The course of sixty lectures furnishes in a plain and concise form the most valuable information for those who are interested in any branch of agriculture, covering, as it does, the most important points in the breeding, rearing, feeding and general management of dairy stock, the economical production of milk, growing and preserving of forage and grain crops, the management of meadows and pastures, management of barns, stables and yards, construction of silos, co-operative dairying, creamery and cheese factory management, judging and marketing dairy products, the chemistry of milk, dairy bacteriology, engineering, animal hygiene and treatment of the common diseases of the dairy cow.

II.—BUTTER MAKING.

The running of separators; ripening and churning of cream; the proper acidity of cream to secure best flavor; how to churn, wash and salt butter so as to avoid specks and mottles; to secure good grain and best methods of preparing for market, are some of the points which receive special attention. As all creamery men should be able to judge butter from a commercial standpoint, students are trained daily in the art of scoring butter by the score-card.

III.--CHEESE MAKING

The work in the cheese room is conducted on a large scale, including the manufacture of several brands of fancy cheese. The fact that there is a demand for these at highly remunerative prices has induced the Regents to provide the necessary means for carrying on this work.

A complete record of every step taken is required of each student. Here is a good opportunity for cheese makers to meet; investigate new methods; make experiments on doubtful points; compare notes, and thus gather in a few weeks knowledge that otherwise would take years to acquire.

IV.—MILK TESTING.

The recent invention of the milk-test has revolutionized the methods of declaring dividends in co-operative dairying. It has been found that the value of milk for both butter and cheese is measured by the per cent of fat content, and nearly all factories and creameries now pay on the "relative value plan." It is therefore necessary for every factoryman to familiarize himself with the best methods of milk testing. The chemist gives a general outline of the work; but in order that each student may have practice in milk-testing, daily exercise is given. Steam, turbine and hand power machines and other apparatus are provided and operated in the laboratory.

The pure and wholesome milk and cream supply for our cities is a matter of vital importance, and there is great need for improved methods of handling milk intended for this purpose. To meet this, a

milk and cream pasteurizing apparatus has been manufactured specially for our dairy school, and a few advanced students will be given instruction in the process.

V.—MOTIVE POWER.

The work in engineering consists of practical talks on the construction, care and manangement of creamery engines and boilers, pumps, injectors, heaters, etc., and work in the practice room.

In the practice room is provided an eight horse power simple slide valve engine, three types of boiler feed pumps, two types of deep well pumps, one injector, two milk pumps, and a steam gauge, which the students have the privilege of examining and operating. Instruction is also given in pipe fitting, placing shafting, babbitting bearings, soldering, etc.

It is the aim to make this work as practical as possible. Questions of interest on the subject are freely discussed.

VI.—FACTORY BOOKKEEPING.

All the essential features of factory accounting, from the receipt of the milk to the returns in net proceeds are thoroughly considered. Paying for the milk according to the fat content or otherwise is fully explained. The students do, in books provided, the actual one month's accounting of a creamery.

REQUIREMENTS FOR ADMISSION.

Experience has shown that students who have had some practical training in the creamery or cheese factory before coming to the dairy school are, as a rule, the ones who are able to make the most of the course; it is therefore required that persons who intend to take this course shall have at least one season's experience before coming to the school. No entrance examination is required.

EXPENSE.

A registration fee of $15 is required of each student. Students can board in either city and reach the school by street car, or board can be secured near the school for from $3.50 to $4.00 per week. Each student is required to supply himself with two white suits, including caps, to be worn during working hours in the creamery and cheese rooms. The suits may be procured for about $1 each.

DAIRY CERTIFICATES.

The Regents will grant Dairy Certificates to students who have taken the course and passed a satisfactory examination and in addition have demonstrated by one year's work in a factory that they are skilled in the art of butter or cheese making, and are thoroughly qualified to take charge of a creamery or cheese factory.

To reach the school from either St. Paul or Minneapolis take the Como Interurban Harriet street car and stop off at Dooley avenue.

Address applications for admission to T. L. Haecker, St. Anthony Park, Minn.

Calendar for School, 1898-99.

OCTOBER	3,	1898	—Entrance examinations and registration.
"	4,	"	—Entrance examinations and registration. Chapel at 4 p. m. Regular classes begin.
"	10,	"	—Literary and class societies meet.
"	18,	"	—Home Dairying begins.
"	29,	"	Examinations.
NOVEMBER	24,	"	—THANKSGIVING DAY: no classes.
"	26,	"	—Examinations.
DECEMBER	23,	"	—Term examinations.
"	24,	"	—Holiday recess begins.
JANUARY	2,	1899	—Entrance and condition examinations.
"	3,	"	—Classes called: work resumed at 8:15 a. m.
"	11,	"	—Home Dairying begins
"	28,	"	—Examinations.
FEBRUARY	22,	"	—WASHINGTON'S BIRTHDAY: no classes.
"	25,	"	Examinations.
MARCH	21,	"	—Term examinations.
"	22,	"	—Term examinations. Alumni reunion.
"	24,	"	—COMMENCEMENT DAY. Tenth annual commencement.
"	25,	"	—Summer vacation begins

STANDING COMMITTEES.

Executive and Finance—Robertson, Drew, Gaines, Shaw, W. Ross, Mabee.

Library—Snyder, Hays, Reynolds.

Agricultural Experiment—Vye, Robertson, Mabee.

Mechanical Department—Green, Hanson, Loomis.

Chemical Laboratory—Arnold, A. Ross.

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